PRINCIPLES OF METAL MINING.

Collins' Elementary Science Series.

PRINCIPLES

OF

METAL MINING.

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PREFACE.

THE art of mining must, to a large extent, be learnt at the mine, either underground or at the surface. The diligent student, however, will obtain much aid from external sources, and it is the object of this little work to convey some elementary knowledge of the principles and facts of mining in a form suitable for the instruction of young miners starting in life—to teach them what to observe—and how to interpret their observations.

The young student should endeavour to add to his own limited experience the larger experiences of many men in many countries—by reading as well as by conversation with his travelled comrades. He should also accustom himself to make written notes of the peculiarities of all mineral deposits with which he may become acquainted, and of the cost and comparative efficiency of all tools, machinery, and materials which may come under his notice.

There are two principles universally applicable to all legitimate mining operations: *First,* That they should not be unduly injurious or dangerous to the men engaged;

second, That they should pay. The first principle has now engaged the attention of the Government; as to the second, it behoves all honest men to set their faces against the system of mining with a view to the interests of stock-jobbers, and to return to the old system of working a mine for the sake of the ore it may reasonably be supposed to contain.

I am now preparing a larger work on the subject, and shall be glad to be informed of any omissions, errors, or supposed errors, which readers of this little work may discover.

J. H. C.

TRURO, *August,* 1874.

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PRINCIPLES OF METAL MINING.

CHAPTER I.

INTRODUCTION.

1. THE art of mining is very ancient, and eminently progressive; and there is abundant evidence that the early miners worked with very rude tools. Cart loads of stone hammers have been found in the old workings of the Lake Superior Copper Mines; wooden shovels from the ancient Cornish Tin Stream Works may be seen in the museum at Truro; and the rag and chain pump was in use in some of the Cornish mines, almost within the memory of men now living.

Even such tools, rude as they seem to be in these days of gunpowder and steam engines indicate a considerable amount of advancement—the pump, more especially; the rag and chain pump, with all its imperfections, was, no doubt, the invention of some man of abilities very superior to those of his neighbours; and probably he met with much opposition from the men who were in the habit of lifting the water out of their shallow pits with large shells or wooden bowls.

The windlass and the wheel-barrow are very old and very simple contrivances, yet their introduction is even now opposed by the native miners of Chili, who continue, as did their ancestors, to carry the ore to the surface on their backs, mounting the "stemples" which are driven into the wall of the lode to serve instead of ladders.

The use of gunpowder for blasting in hard ground, said to have been first used in the parish of Breage in Cornwall, is scarcely three centuries old; and even yet the ancient mode of rendering the rock brittle, by first heating it by means of a fire of brushwood kindled in the "end," and then throwing cold water upon it, is still in use in some of the continental mines.

2. These facts may serve to illustrate the extreme conservatism of the race of miners; a conservatism which has induced many miners to look with dislike, and even with contempt, upon every kind of knowledge, except that which may be learnt in the mine itself. Such prejudices are now, however, happily passing away, and the best miners are beginning to see that the study of various branches of science may not only accompany, but precede with advantage, actual work in the mine.

Improvements and modes of working have now become so numerous, that all their details can scarcely be mastered by any one man, and this has led to a division of labour in mining, as in all the useful arts. The different kinds of knowledge bearing upon mining, as well as upon other pursuits, have been arranged in kindred groups, called sciences, or more accurately branches of science, each of which, it would be the labour of a lifetime to master completely. Yet a good miner should be acquainted with the rudiments of many of them, as he will be sure frequently to see advantageous modes of applying such elementary knowledge, and he will thus know when he should call in the special aid of the chemist, geologist, mineralogist, or mechanic, as the case may be.

It is especially important that every miner should be acquainted with certain primary facts, such as the properties of matter, the laws of force, the relative strength of materials, etc., and such elementary knowledge is by no means difficult to acquire.

3. The science of **Mechanics** treats of the action of masses of matter upon each other. **Hydraulics** is simply the mechanics of *liquids;* **Pneumatics**, the mechanics of

gases and *vapours.* It is evident that in mines where masses of matter are always being moved, and which need to be continually freed from water and foul air, an elementary knowledge, at least, of each of these branches of science is of the utmost importance to all engaged.

In metal mines, nothing is more common than to hear men complaining of the foul air in a bad "end," and with good reason, since the air is frequently quite poisonous. Yet the remedy is often easy, and in the men's own hands. One sees, in such foul ends, the ore and rubbish allowed to accumulate behind the men to a height of several feet before it is trammed back to the shaft, so shutting up the natural path of the fresh and pure air. The miner, in that thoughtlessness which is born of ignorance, goes on in his old way; the captain, sometimes not much better instructed than the men, makes no remark, and so the men "perish for lack of knowledge."

Sometimes one meets with a man, who, not having studied pneumatics, has yet by his own methods of close observation learnt the lesson which that science would teach; but even he has only learnt it after long and injurious experience. Such men are everywhere rare, but it would be easy to teach all men and all boys, and to impress the lesson upon their minds by a few simple experiments, that the cool, pure air passes into the end on the *floor* of the level, while the heated impure air rises to the *back* to pass out; and if either the cool or the heated currents be obstructed, stagnation will be the result. This subject will be dealt with in detail in the chapter on ventilation.

4. The principle which underlies the great majority of ore-dressing operations, is to take advantage of the different specific gravities of the ore and the waste. The same principal is at the bottom of the beautiful art of "vanning." It ought not to be necessary to insist upon the great value of this art to the metal miner; yet it is truly astonishing to find how very few miners, even tin miners, are able to practice it. The speed and accuracy with which

a practised vanner determines the value of a sample of tin ore, fills the beholder with wonder and delight. No words can describe the peculiar motions of the wrist which serve to separate the ore on the shovel from the waste. The only way to learn is to watch closely the movements of a proficient, and to try to imitate him as closely as possible.

The vanner finds by experience what science teaches from pure reasoning, that clean water is essentially necessary, if the results are to be accurate; and the tin-dresser who is once thoroughly impressed with this fact will be the best dresser; because he will see the importance of securing every drop of this requisite which comes within his reach.

5. The science of **Geology** should be known in its broad outlines to all miners, especially that part of it which treats of the peculiar deposits of metal or coal ordinarily sought for. For want of such elementary knowledge, many important facts have been but imperfectly understood by the miner. Men will work for a lifetime in a mine, and will yet be totally ignorant of the peculiarities of an adjoining mine, not to speak of those of mines in other districts or in foreign countries. How few Cornish mine agents even have ever read Mr. Henwood's most valuable works on the metalliferous deposits of their own county, published thirty years ago! How few ever commit to paper their observations on the mines in which they spend their lives! In the absence of such written notes, facts are apt to fade away into a general haze in the mind, and so become lost, not only to others, but often even to the observer himself.

For centuries past no country has possessed so many good mines, or produced so many good miners, as the one little county of Cornwall; yet the mining proverb, "where it is, there it is," still holds its own in the county, and will continue to do so until observations are multiplied and intelligently recorded and compared.

The phenomena connected with bed mining are much less

obscure, and their uncertainties have been reduced, perhaps, to a minimum; but costly mistakes have frequently been made, which might have been avoided by the application of a very little scientific knowledge.

We may reasonably hope that a brighter future is at hand, if our miners be supplied with what is really known in early life. Why should we not teach a lad all the little that is certainly known of the laws of metalliferous deposition, together with the peculiarities of the "faults," "troubles," heaves," etc., of bed and vein mining, before sending him to the mine at all; instead of allowing him to spend his life in painfully acquiring such knowledge—the A B C of mining—and too often to die and carry away what he has learnt, leaving his brother miners none the wiser?

6. Mineralogy is undoubtedly a science of great importance to all practical miners, even the humblest. Many miners are perfectly alive to the minute points of difference existing between the different minerals ordinarily coming under their notice, although they have usually picked up such knowledge hap-hazard. Still, stories of valuable minerals having been thrown away in ignorance of their true value, are very common in all mining districts, and some, at least, of these stories have been proved to be true. Even in such a tin-producing county as Cornwall, large and valuable lumps of "wood-tin" and "toad's-eye" tin have been built into hedges, and fine lumps of silver ore were found a few years since built into hedges in the eastern part of the same county. No doubt, indeed, such mistakes have occurred within the knowledge of most miners.

But it is only the mistakes *which have been discovered* that *can* be known; it is very probable that the great majority of such mistakes are never found out at all. The only safeguard for the future is in the multiplication of mineralogical observers, with eyes sharpened by practice and by knowledge to discover minute points of difference—men accustomed to look for stones of strange or

peculiar appearance, and in the habit of compelling them to give an account of themselves. To aid such men, each mine should have its glass case filled with the productions of the mine; every literary institution, in a mining neighbourhood, should have its collection of the minerals of the district nicely labelled and catalogued; and the larger towns should try to get illustrative specimens of every mineral substance known, to serve for comparison with any peculiar substance which might be discovered.

7. To the miner, the science of mineralogy is of greater importance than that of **Chemistry**, yet it naturally leads to an elementary knowledge of the latter science. Here, too, an *educated* may have over an *untaught* miner an immense advantage, by simply making himself acquainted with the operation of a few simple tests, and especially by learning to use the mouth-blowpipe. To be able to make an accurate analysis requires months of study and years of practice; but a man skilled in the use of the blowpipe will often be able to determine in a few minutes whether a complete analysis is desirable or not. In Cornwall many miners have recently acquired this very valuable accomplishment, in a sufficient degree, by one or two winters' practice in the evening science classes of the Miners' Association of Cornwall and Devon; and it is much to be desired that similar classes should be established in every mining district throughout the United Kingdom. Of course, it is not argued that these different branches of science—mechanics, geology, mineralogy, chemistry—should each and all be known in an equal degree by all engaged in mining, or that all together would suffice to make a man a miner without practice in the mine. It is simply argued that a good engineman, and, therefore, also a bad one, will be the better for a knowledge of the properties of steam and the chemistry of the furnace; the tributer for a knowledge of geology and mineralogy; the pitman for a knowledge of the relative strength of materials; the ore dresser for the elementary principles of hydrostatics; while even the lander at the

shaft's mouth, and the boys and girls who "buck" the ore, will be the better for a little elementary knowledge of mineralogy. These sciences are now taught in the science classes in connection with the Department of Science and Art throughout the United Kingdom, and are dealt with in the series of text-books, of which this work forms one, and to which the student is referred. A brief reference to the special bearings of the sciences of geology and mineralogy upon the art of mining, will be given in the next three chapters, after which we shall proceed at once to deal with the more technical parts of the subject.

CHAPTER II.

THE GEOLOGY OF MINING DISTRICTS.

8. The Crust of the Earth.—The ground upon which we tread, as deep down as we know anything about it—is often spoken of as the "crust of the earth." The science of geology teaches us what this crust is, and that it was not always in its present condition. What is now dry land has been covered with the waters of the sea once, or many times; while the sea is gradually being filled up with the waste of the land, and, at the same time, portions of its bottom are gradually being elevated by forces acting from below, so as to form dry land. The study of these various changes, both past and present, belongs to the science of geology, more particularly treated of in the text-book of that science published in the present series, to which the student is referred for more detailed information than can be here given.

9. Classification of Rocks.—It is found by geologists that the various rocks which go to form the so-called crust of the earth, may be primarily divided into two great groups, called **stratified** and **unstratified**.

10. Stratified Rocks.—The stratified rocks have been mostly, although not exclusively, formed by the agency of water, and are hence called aqueous. They form more or less regular "beds," often extending, with but little variation, over large tracts of country, and resting one upon another in regular order.

11. Unstratified Rocks.—The unstratified or igneous rocks, as they are frequently termed, on the contrary, are much less regular in their mode of occurrence, and they have been formed in quite a different manner; sometimes they seem to have been forced up from below through the stratified rocks, or spread out over their surfaces in the manner of lava currents from volcanoes. Occasionally, igneous rocks occur regularly stratified between beds of ordinary stratified rocks, but such beds are rarely of very great extent.

12. Metamorphic Rocks.—Besides the ordinary stratified rocks, and those which are clearly unstratified, are others which occur, indeed, in regular order like the former, but which appear to have been much altered by heat, pressure, electricity, or other agencies. They are generally harder, much more crystalline, and frequently contain rich stores of valuable materials. These are the so-called **metamorphic** rocks. Among the more important of the regular stratified rocks may be mentioned limestone and sandstone; granite, greenstone, and elvan porphyry, are common unstratified rocks; while roofing-slate, mica-schist, and gneiss are metamorphic. These will be more minutely described in the next chapter.

The stratified rocks, as already said, are found to succeed each other in a regular series; having, however, frequently some of its members missing, but not occurring in a reversed order. Of this series, those which appear at the top, or nearest the surface, are necessarily the most recent.

13. Igneous Rocks.—The igneous rocks are of various ages, some masses of granite, for example, being much more recent than others. The stratified and metamorphic

rocks were originally deposited horizontally, or nearly so, although now frequently found much disturbed, or resting upon the irregular surfaces, or edges of older rocks; unstratified rocks occur under almost every possible condition. Fig. 1 shows the stratified metamorphic "devonian" shales or "killas," *a*, resting upon the irregular surface of granite; *b*, at the mines north and south of Carn Brea Hill in Cornwall.

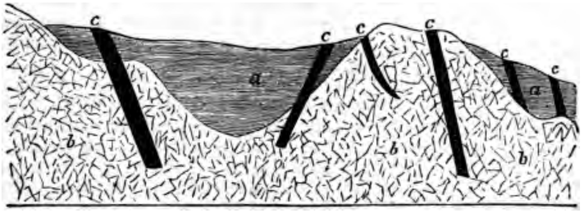

Fig. 1.—*a*, Killas; *b*, granite; *c*, elvan.

The following table gives the names of the leading groups or divisions of stratified rocks, including references to some of the chief mineral deposits occurring in them which are of interest to miners.

No.	Formation.	Chief Mineral Contents.
1.	**Post Tertiary.**	—Stream tin of Cornwall in river gravels. Copper deposits of Lake Superior. Alluvial gold of Australia and California.
2.	**Pliocene.**	..........Large deposits of bones and excrement of fishes (known as coprolites), obtained by a rude species of mining from Suffolk and Essex, and used for making artificial manures.
3.	**Miocene.**	..........Some of the lignites or brown coals of Ireland are of this age. Lignite beds of Bovey Tracey in Devon, Antrim, Mull, Austrian Alps, Germany, and Vancouver's Island.
4.	**Eocene.**	............Lignites of Tyrol, Venetian Alps, and Southern Styria. Gypsum of Montmartre.
5.	**Cretaceous**	.......Iron ore beds of Sussex. Copper ores of Algiers and Chili. Lignite of Gosau, in the Austrian Alps, and of Santa Fe de Bogota, in S. America. Coal of Moravia.

No.	Formation.	Chief Mineral Contents.
6.	**Oolitic & Liassic.**—	Coal of Kimmeridge, Brora, Funfkerchen, and Steièrdorf, in S. Hungary; Pennsylvania. Brown coal of N. Germany. Copper deposits of the Bannat, in Austria, and of Department l' Aveyron, in France. Iron ores of Cleveland and Rosedale, in Yorkshire.
7.	**Trias**...............	"Letterkohle" of South Germany. Coal of Virginia, U.S., and of New South Wales (part). Copper of Chessy, in France. Lake Superior, Connecticut, New Jersey, and Pennsylvania (according to some authors).
8.	**Permian**...........	"Branschiefer" of Germany and Bohemia. Coal of India and of New South Wales (part). Copper deposits of the west side of the Ural Mountains. Mansfeld, in Prussia; Hesse, Thuringia. Rock salt of Worcestershire and Cheshire. Clay ironstone of the coal measures.
9.	**Carboniferous**...	Coal measures of Gt. Britain and Ireland, France, Belgium, Prussia, Bohemia, Moravia, Spain, United States, and Nova Scotia. Anthracite of South Wales, Ireland, and Pennsylvania. Coal of New South Wales (part). Lead mines of Derbyshire and Cumberland.
10.	**Devonian**.........	Coal of New South Wales (part). Tin, copper, iron, and lead lodes of Cornwall and Devon. Copper lodes of Wexford.
11.	**Silurian**	Anthracite of County Cavan, Ireland; of Isle of Man and Norway. Graphite of Cumberland. Copper of the east flank of the Urals.
12.	**Cambrian**.........	
13.	**Laurentian**.......	Graphite beds of North America. Copper of Norway and Sweden.

Some of these mineral deposits occur as if filling up the irregular fissures known as veins or lodes; others occur as regular seams or beds.*

14. Tin, copper, iron, and other minerals, also occur in

* It should be mentioned that the veins are frequently much newer in their formation than the rocks in which they occur, but it cannot always be said how much newer.

granite, greenstone, and other rocks of various ages, near their junctions with the aqueous or metamorphic rocks. China clay is very seldom obtained by mining, and will not therefore be here further alluded to. It occurs in connection with most of the granite masses of the west of England.

15. Coal or Lignite occurs also in China, Japan, New Zealand, the Falkland Islands, and in South-eastern Africa, but the geological age of the containing rocks is somewhat uncertain. Igneous rocks occur in every one of the foregoing series of rocks, and are often sought for as building or ornamental stones, or for road metal. They are of two kinds, called "volcanic" and "plutonic." Volcanic rocks, such as lava, pumice, basalt, etc., have been thrown out from volcanoes in a melted or half melted state, and have afterwards cooled down into solid masses. Plutonic rocks, such as granite and porphyry (elvan), seem to have been formed at greater depths, and under a pressure of many thousand feet of rock. They are now visible through the removal by denudation of their covering rocks. "Elvans" are shown at *cc* in fig. 1.

To the metal miner these igneous rocks are of especial interest, as it is but seldom that very rich deposits of ore are found at any great distance from them. Their disturbing influence of the surrounding stratified rocks seems often to be the cause of such deposits; but although this is so on the large scale, it is not always so in detail. Sometimes in Cornwall, for instance, elvan courses "make" very rich deposits; at other times, but not so commonly, their immediate influence seems to be unfavourable.

16. The different substances sought for by the miner occur usually either in "veins" or in "beds," but sometimes in "irregular" deposits known as "pockets," "carbonas," etc. The ores of tin, copper, lead, zinc, and many other metals occur mostly in "rake" veins or "lodes," or in "pipe" veins or "shoots," but occasionally in pockets or alluvial beds. Coal occurs always in beds. Iron, very

frequently, in all the different forms of deposit. The tools and appliances for these different kinds of mining are on the whole a good deal alike, but lodes and beds are so essentially different in their conditions that very different modes of working are found necessary, and it will be well to distinguish them from the outset. Irregular deposits or pockets are worked by one or the other method, or by modifications, including some of the peculiarities of each, as may be found necessary in each peculiar case. The chief peculiarities of vein mining and bed mining are detailed in the Sixth and following chapters.

CHAPTER III.

MINERALS AND ROCKS.

17. Any natural substance which is not of animal or vegetable origin, and which is in all parts of the same composition, is called a **mineral**. Among miners, however, the term is only applied to such substances as are usually obtained from mines. These are more properly called **ores**. Coal, also, although of vegetable origin, and therefore excluded by the strict application of the above definition, must be here included with them.

18. Composition of Rocks.—Many rocks are made up of two, three, or more distinct minerals; others consist of impure masses of some one mineral. Thus, the well-known rock called **granite** is a mixture of the three minerals, *quartz*, *felspar*, and *mica;* while ordinary **limestone** is a mass of more or less impure carbonate of lime, or *calcite*. Hematite, limonite, rock salt, coal, and many others of the substances mentioned below occasionally thus occur as rock masses.

19. Every miner should be well acquainted with the more commonly occurring minerals, and the rocks formed from them, and especially with those mentioned in the follow-

ing lists. Pure specimens of these contain the percentages of the metal sought as shown in the second column.

1.—METALLIC MINERALS OR ORES.

Name. Native Metals.	per cent. of Metals.
Gold,	100
Silver,	100
Platinum,	100
Mercury,	100
Copper,	100
Bismuth,	100
SILVER ORES.	
Argentite, or grey silver ore,	87
Stephanite, or brittle silver ore,	70
Pyrargyrite, or dark red silver,	59
Proustite, or light red silver,	65
Kerargyrite, or horn silver,	75
MERCURY ORE.	
Cinnabar,	86
COPPER ORES.	
Cuprite, or red oxide of copper,	89
Melaconite, or black oxide,	79
Chalcocite, or grey copper ore,	80
Chalcopyrite, or yellow copper ore,	34
Erubescite, or purple copper ore,	55
Malachite, or green copper ore,	57
Chessylite, or blue copper ore,	55
TIN ORE.	
Cassiterite, or tin ore,	79
LEAD ORES.	
Galena, or lead glance,	87
Cerussite, or carbonate of lead,	71
Anglesite, or sulphate of lead,	70
Pyromorphite or phosphate of lead,	76
IRON ORES.	
Magnetite, or black oxide of iron,	72
Hematite, or red oxide of iron,	70
Limonite, or brown oxide of iron,	59
Chalybite, or carbonate of iron,	42

ZINC ORES.

Name.	per cent. of Metals.
Blende, or "Black Jack," . .	67
Calamine, or carbonate of zinc, . .	52

MANGANESE ORE.

Pyrolusite, or oxide of manganese, .	63

TUNGSTEN ORE.

Wolfram, or tungstate of iron, . .	60

ANTIMONY ORE.

Antimonite, or grey antimony ore, .	71

20. Besides these, iron pyrites, or "mundic," is often wrought as an ore of sulphur, of which it contains 54 per cent. It also frequently contains small quantities of copper, silver, and gold.

2.—NON-METALLIC MINERALS OR SPARS.

Quartz, or "*spar.*"
Fluor spar, *blue John* or *cann.*
Calcite, or *carbonate of lime.*
Mica, or "*shell.*"
Gypsum, or *sulphate of lime.*
Hornblende.
Serpentine.
Dolomite.
Chlorite, or *peach.*
Schorl, or *cockle.*
Barytes, or *heavy spar.*
Rock salt.
Coal.

These are the most important of the minerals which will come under the notice of the young miner, who would do well to make himself acquainted very minutely with their peculiarities and properties, by the examination and comparison of actual specimens if possible.*

* Complete descriptions of these and many others, with which he may meet from time to time, will be found in the author's *First Book of Mineralogy*, published in the present series of text-books.

21. The student should also make himself acquainted with the rocks mentioned below. This will be easy after he knows well the minerals already mentioned.

Granite.—A granular compound of *quartz*, *felspar*, and *mica*.

Gneiss.—A foliated compound of the same minerals arranged in irregular layers.

Elvan.—Nearly the same ingredients, but differently arranged. The mass of the rock is frequently an uncrystallised felspathic substance, through which crystals, or rounded grains of *quartz*, and crystals of *felspar*, or flakes of *mica* are interspersed.

Syenite.—A granular compound of *quartz*, *felspar*, and *hornblende*, often much like granite in appearance.

Schorlyte, or Schorl Rock.—A granular compound of *quartz* and *schorl*. Occasionally the quartz disappears, and the schorl forms a very compact mass of somewhat dull and earthy appearance, very hard and tough.

Felsyte.—A granular compound of *quartz* and *felspar*.

Mica Schist.—A foliated compound of *quartz* and *mica*.

Quartzyte.—A granular rock composed of *quartz* only.

Serpentine.—The massive impure form of the mineral of the same name; feels smooth and somewhat greasy, and is easily scratched with a knife.

Greenstone, Whinstone, or Trap.—A compound of some kind of *felspar* with *hornblende;* sometimes granular, but more frequently compact. It frequently contains much magnetic iron diffused through it in grains. It is sometimes called *diorite*. Miners often call it ironstone.

Basalt is much like **Greenstone** in appearance, but is much less tough and hard, and usually somewhat heavier. The so-called toadstone of the coal and iron districts of the centre of England is a kind of basalt.

Clay Slate differs much in different districts. One form is very hard, and splits up readily into large strong plates, much used for roofing. In another kind, the "killas" of the Cornish miner, the cleavage is less perfect, and the rock is more brittle.

Limestone is the massive form of the mineral *calcite*.

Dolomite is the massive form of the mineral of the same name.

Gypsum is the massive form of the mineral of the same name.

Many other rocks will come under the notice of the miner; but a correct appreciation and recognition of these will be of great assistance to him in his explorations.

CHAPTER IV.

THE NATURE OF MINERAL VEINS.

MINERAL veins occur mostly in three different forms, known as *Rake-veins*, *Pipe-veins*, and *Flats.*

22. Rake-veins or **Lodes** appear to occupy fissures in the earth, sometimes parallel to, sometimes cutting across, the general bedding, and even the cleavage of the rocks. They are generally very irregular, often several miles in length, of a width varying from less than one inch to many feet, and they extend downwards to an unknown depth. Their contents vary extremely, some parts containing ores, others being filled with matter of no commercial value. The orey parts are often spoken of as "shoots of ore." When the orey parts are wide and rich, and separated from similar riches by thin and unproductive parts, they are in some districts called "gash-veins." A cross section of a remarkable group of lodes at Wheal Basset Copper and Tin Mine, in Cornwall, is given on fig. 2, on a scale of seventy fathoms to one inch.

23. Pipe-veins are masses of ore, generally parallel to the stratification of a country, very regular in their dimensions, but often greatly extended in the direction of the dip of the rocks. They are more numerous in limestone than in slaty rocks.

24. Flats or **Floors** consist of layers of mineral matter lying more or less horizontally between the beds of their containing rocks, and sometimes forming a connection between two parallel lodes.

25. In connection with some lodes, irregular masses of mineral matter, called *carbonas*, are found. There are irregular bunches, of sometimes very many fathoms in each direction, and often attached to the lode by very small portions or "pipes" of ore. In some places, where the lodes are very narrow and numerous, the whole rock seems to be permeated with mineral matter, which is, never-

theless, accumulated in the thin veins referred to, and in the joints. These are in Germany called *stockwerke*. No English name has come into common use, but they are occasionally spoken of as "stockworks."

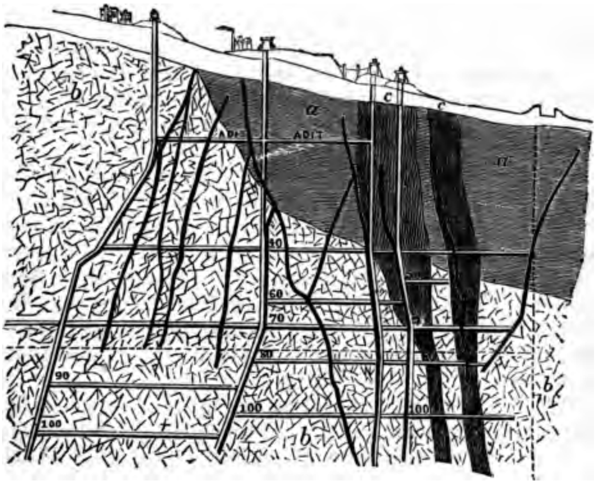

Fig. 2.*—*a*, *á*, Killas; *b*, *b*, granite; *c*, *c*, elvan.

26. Of these different kinds of mineral deposits, the lodes are certainly the most important; and as they are very numerous, and have been largely worked in the west of England, our description will apply chiefly to that district.

Many of these have evidently been opened several times successively, and filled in more or less completely with matter of different kinds. Evidence of this is afforded by the "combed," "brecciated," and "conglomerate" structure frequently met with in lodes. Besides the actual filling in of the fissure, the country on each

* This figure is from a survey by Capt. Maynard of East Pool Mine.

side is frequently much altered, "mineralised" as miners say. This altered band, which in tin mines is often sufficiently rich to pay for removal, is variously known as capel, stickings, selvage, and by several other names. In some parts of Cornwall, especially in the china clay districts, the tin lodes are little more than highly mineralised "joints," only rich at intervals, but sometimes the clay appears to have been indurated and impregnated with quartz, schorl, and tin ore for many feet on each side of the actual fissure, especially in the neighbourhood of certain cross-veins.

Sometimes these mineralised joints are so numerous that the whole mass of rock has to be removed, and afterwards picked over, or dressed entire. This is the case in many places about the centre of Cornwall, the works resembling the so-called "stockwerke" of Germany. Such works are usually rather quarries than mines, and the author has known a produce of only 3½ lbs. of saleable tin ore in the ton of stuff, to yield a profit for years together.

27. The principal tin and copper lodes of each mining district in Cornwall and Devon occur in parallel groups, and, on the whole, have a bearing differing but little from that of the granite axis of the two counties. From Tavistock to Hayle this axis bears about E.N.E., but from Hayle to the Land's End, a marked change of direction occurs, and this is accompanied by a similar change in the direction of the lodes. Very similar facts may be observed in other mining districts all over the world.

Lodes very seldom pass perpendicularly into the earth, for more frequently they have an inclination, dip, or underlie one way or the other, as shown in fig. 3, which represents a lode in granite underlying south. This underlie is in Cornwall always reckoned at so many feet in a fathom from the perpendicular. In any group of lodes, some may underlie one way, some the other, as in fig 2, p. 25.

The average width of the tin and copper lodes of Corn-

wall and Devon is about 3 feet 6 inches; the average underlie is 20° from the perpendicular, or 14 inches in a fathom. The lodes frequently split up into branches, and sometimes these branches re-unite, when the included portion of country is called a "horse." A "horse" is shown at *g*, in fig. 3.

Besides the so-called right running or champion lodes, there are other veins known as caunter lodes, cross courses, trawns, guides, flucans, or gossans. Caunter lodes are those which contain tin or copper, or other ores, but have a direction different from the champion lodes. They occur especially in the central parts of Cornwall.

Fig. 3.—*a,a*, "Hanging wall" and "capel" of lode; *b,b*, "foot-wall" and "capel;" *e,e*, "back" of lode; *f*, granite; *g*, a "horse."

28. Cross Courses are veins whose direction is nearly at right angles to the chief lodes of any particular mining district. When they contain clay they are known as flucans, and this clay is sometimes so very impervious to water, that they form the best of all possible boundaries between neighbouring mines. Sometimes the cross-veins yield iron ore or lead ore in large quantities; this is particularly the case about the centre and east of Cornwall. Near their points of intersection with the lodes, they frequently contain portions of ore similar to that in the lode, and also small quantities of more unusual ores, as those of cobalt, nickel, antimony, and silver. In St. Just, the cross veins are known as trawns, or guides,

in St. Agnes, as gossans. The average width of cross veins is a little more than that of the lodes, their underlie is somewhat less, but, like them, they dip more frequently towards than from the nearest mass of granite. In other respects they closely resemble the lodes, having similar, although somewhat less, variations in width, underlie, contents, etc. They also split and re-unite like the lodes, but perhaps not so frequently.

Fig. 4 shows the mean bearing of the tin and copper lodes, caunters, and cross courses in Cornwall. The experience gained in Cornwall and West Devon has made the miners of this district famous in all parts of the world, and their services are in continual requisition for the discovery and working or "exploitation" of mineral veins. In searching for minerals in untried countries, they are, in the first instance, guided by the general conformation of the country. Practically, the unlearned Cornishman has looked for a surface contour more or less resembling that of Cornwall in its undulating character, and has especially searched the flanks and bases of hills of moderate elevation for the outward signs of mineral wealth. Among these outwards signs may be mentioned, "shodes," "gossans," "springs," and "stains," visible either in such situations, in mole-hills, the ejecta of burrowing animals, the sides of ravines and water-courses, etc. He also closely examines all such river sands as may come in his way by vanning.

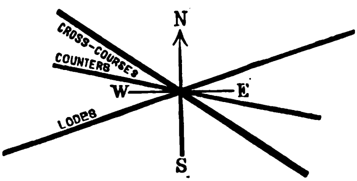

Fig. 4.—Mean Direction of Tin and Copper Lodes, Cross Veins, and Caunters in Cornwall.

29. Shodes are stones of ore, often more or less waterworn, which are recognised by the miner as similar to those he has seen near the backs of lodes. He argues

that such stones can only be brought by natural agencies *down* hill, and, therefore, goes upwards, searching as he goes, until such shodes no longer appear. At or near the point of disappearance, he searches for the lode by the method of "costeaning," presently to be described.

30. **Gossan** (pronounced gozzan) is the name given to the cellular quartz and ferruginous matter, frequently found in large quantity at the outcrop or back of a lode. The existence of much gossan indicates more especially lodes of copper, lead, iron, sometimes of gold or silver; but tin lodes have frequently no gossan.

31. **Springs** of water frequently indicate the outcrop of a lode, and even in seasons where no water is visible, a slight depression or a superior greenness of the herbage often indicates their position with accuracy.

32. **Stains** of various kinds often occur in connection with these springs. Thus, stains of red, yellow, or brown, very frequently indicate the existence either of iron lodes, or of the iron gossans of other lodes. Green and blue stains frequently indicate deposits of copper; greyish, bluish, or slaty tints, often indicate lead. Some lodes have been discovered by the exposure of the sides of ravines, produced by running water; others, by the character of the material thrown out by moles or other burrowing animals from their galleries. Some have been discovered by farmers in the material thrown out by the plough, by miners working alluvial deposits, or by men engaged in making railway cuttings, or opening quarries.

33. A very perfect cleavage in the rocks, or a very distinct porphyritic structure in the granite rocks of any neighbourhood are not looked upon as favourable indications. On the other hand, if the component minerals of the igneous rocks appear indistinctly blended into each other, the cleavage of the slaty rocks indistinct, and the separate plates not too glossy, the indications are regarded as favourable, if they occur in a suitable situation.

34. The process of costeaning has been already referred to. It is as follows: The general bearing of the lodes of any

district is first ascertained by the discovery of some one champion lode, or by the general indications of the country. Let us suppose this general bearing to be, as in Cornwall, nearly east and west. Pits are then sunk in likely situations, say from 5 to 20 or 30 fathoms apart, and deep enough to be below the disturbed subsoil or alluvial deposit of the place. These pits, in the case indicated, will be in a line nearly north and south. A gallery or level is then drawn, so as to make a communication between these pits, and in doing so the lode, if situated between any two pits, cannot fail to be discovered. This process is called costeaning, and it is on the whole the very best which can be adopted in ordinary cases, and much preferable for the purpose to the boring which is so commonly and properly resorted to in bed mining.

CHAPTER V.

"HEAVES," ETC.

35. In following a lode it frequently happens that a cross-vein is reached, after cutting through which the lode is not to be found on the other side. In such cases it is said to be "heaved," and it becomes necessary to drive on the cross-vein in order to discover it again. These heaves are a source of much loss to the miner and his employers, as they are sometimes of great extent, occasionally as much as 70 fathoms; so that it is a matter of great importance to the miner to be able to say in which direction he is most likely to find it by driving. No rule can be given which has absolutely no exceptions, but a very high degree of probability is attainable.

36. Direction of Heaves.—If the lode is found by driving to the right on the cross-vein, it is said to be a right hand heave; if to the left, a left hand heave. In

figs. 5 and 6 the lodes are heaved to the left, whether the miner is approaching the cross-vein from the east or the west. In Cornwall, many more right hand than left hand heaves are known.

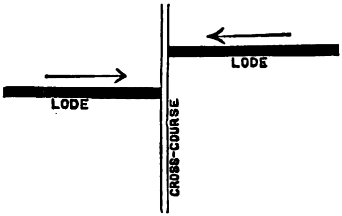

Fig. 5.

It is but seldom that the lode and cross-course form an intersection at right angles as in fig. 5; far more frequently a greater angle and a smaller angle are observable as in fig. 6. In Cornwall, of 272 cases of intersection recorded by Mr. Henwood, 57 were unaccompanied by heaves; and of the 215 remaining, 181, or more than 84 per cent., were found by driving on the side of the greater angle; and 34, or less than 16 per cent., on the side of the smaller angle. In other words, by driving on the side of the greater angle, there are five chances to one that the lode will be met with.

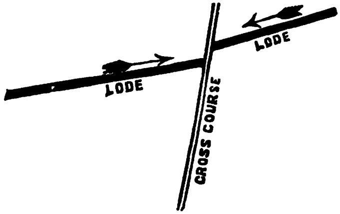

Fig. 6.

Even this is not all that the study of known intersection teaches. Several other rules will add largely to the chances of success. Thus parallel lodes of similar underlie will be heaved in the same direction in the great majority of cases. Those with the greatest underlie will mostly be heaves to the greatest extent. Lodes of similar bearings having opposite underlie, will not unfrequently be heaved in opposite directions. By studying the bearing and underlie, therefore, of other lodes intersected by the

cross-course in question, much additional information will be gained.

37. **Extent of Heaves.**—Some idea of the extent of the heave may also be obtained in many instances, as it has been observed that the heaves occasioned by large

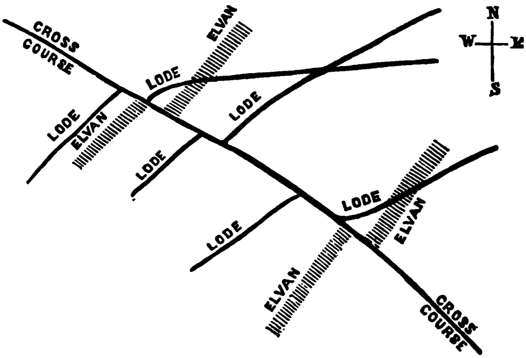

Fig. 7.

cross-courses are mostly greater than those occasioned by small ones. Fig. 7 shows the heaves of three lodes and two elvans by a cross-course in the neighbourhood of

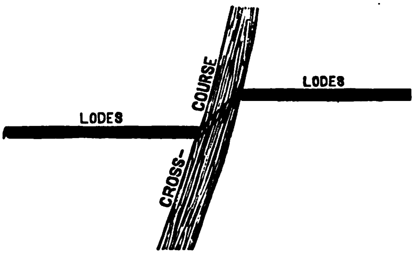

Fig. 8.

Camborne, in Cornwall. The science of Geology very fairly accounts for these phenomena in many instances;

but the elementary student of mining had better defer his study of such theoretical matters.

38. Indications.—The direction of the heave is sometimes indicated by stains in the cross-course, a change in its mineral character, a stream of water, or even by leaders of ore which connect the two parts of the lode, as shown in fig. 8. All such appearances will be carefully sought for and noted by the young miner who wishes to succeed.

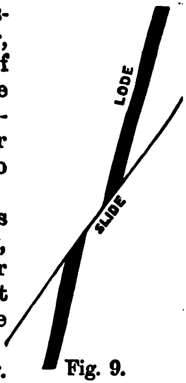

Fig. 9.

39. Slides are displacements of lodes occasioned by thin veins, often of clay, which have a general bearing similar to that of the lode, but a different underlie, as in fig. 9. Such slides are by no means so common as heaves.

A kind of reversed slide, shown in fig. 10, which throws up the lode, is not uncommon in the mines of St. Agnes, Cornwall. As the disturbing vein contains ferruginous matter, much like the gossan found on the outcrop of many lodes, the slide itself is here frequently called a gossan. As a rule, slides are by no means so common as heaves—and they are often still less liked by the miner than heaves. The gossans of St. Agnes, however, are in some respects a positive advantage, as they bring up the lode nearer the surface, where it can be more easily and cheaply worked.

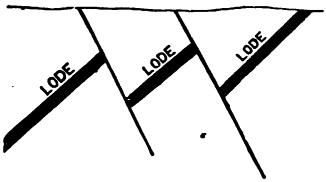

Fig. 10.

CHAPTER VI.

DEAD WORK IN VEIN MINING.

40. Dead Work.—This includes all such mining operations as are carried on underground for the purpose of obtaining the ore, excepting only the actual "getting." It will therefore include all the shafts sunk and levels driven, not only at the commencement of the undertaking, but also such works as are or ought to be kept in advance of the productive portions of the mine, so as to yield a continual output. **Productive** work is a term applied to the actual getting of the ore so "laid open."

41. Shafts.—The situation and underlie of the lode having been sufficiently ascertained by the preliminary explorations, one or more shafts are now sunk, generally on the side to which the lode inclines; or if there be two or more lodes near to each other, between these.

42. Drainage.—As this shaft soon becomes full of water, at least in its lower part, it becomes necessary to devise some means of drainage. Sometimes this can be effected, partly or entirely, by driving a level from the nearest low ground, so as to reach the shaft in depth. Such a level is called an "adit." Adits are frequently of great importance to the mines drained by them, and should always be kept in thorough repair, as even in the case where pumping is necessary for the workings below the adit, the amount of pumping power required may be much reduced by only raising the water to the adit level, instead of lifting it at once to surface.

From the shaft, both above and below the adit, levels are driven right and left, often at distances of 10 fathoms, or 60 feet, apart. As these levels become extended, it is necessary to open communication between them by means of smaller shafts or "winzes," which do not reach the surface, for purposes of ventilation, and also as a means of discovering the nature of the lode between the levels.

Fig. 11 shows the various "shoots of ore" in part of Snailbeach mine, laid open by means of the levels there shown. Similar shoots of ore occur in the lodes of Cornwall, but they are connected by poorer portions of the lode instead of being separated by masses of killas.

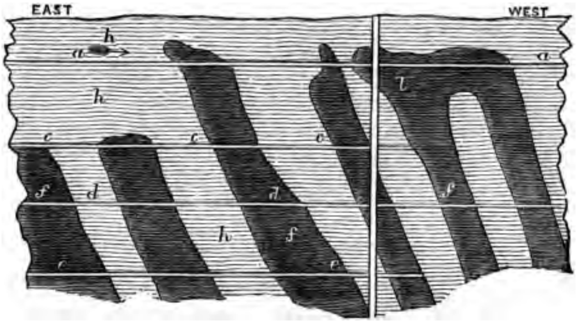

Fig. 11.—SHOWING SHOOTS OF ORE AT SNAILBEACH MINE. *a, a,* Adit level; *b,* shaft; *c, d, e,* levels; *f, f,* shoots of ore dipping west; *h, h,* killas.

43. The terms "back," "hanging-wall," "foot-wall," and "end" are continually used by miners. In Cornwall they are applied as in fig. 3. The "end" is better seen at *c* in fig. 20, which is put a little in advance of the stope *a.* The remains of a "winze," which was the means of opening out the deposit of ore at *a,* is shown in the same figure at *d.*

44. Form and Dimensions of Shaft.—The shafts are mostly rectangular in section, varying from $5' \times 3'$ up to $12' \times 9'$, and occasionally larger. In Cornwall a common size is $10' \times 8'$, and the shafts are generally larger in hard ground than in soft ground. This is for a double reason —1*st*, that there is no difficulty in sinking a small shaft in soft ground, while in blasting ground a small shaft is sunk with great difficulty, owing to the want of room for the blasting operations. 2*nd*, the difficulty of securing the

sides of a shaft in soft ground increases rapidly with the size of the shaft, especially when the section is rectangular, while there is no such difficulty in hard ground.

Shafts in vein mining are almost always vertical in their first portions, say from 30 to 70 fathoms, after which they usually follow the underlie of the lode, as shown in fig. 2. Occasionally, however, shafts are made to follow the underlie of a lode from the surface, and shafts which are vertical throughout are of late years not uncommon, communication being effected by cross-cuts. A few shafts are inclined, following the *course* of the lode instead of its *underlie*, as shown in fig. 12, which represents the workings around the Boscawen shaft at the famous Botallack mine.

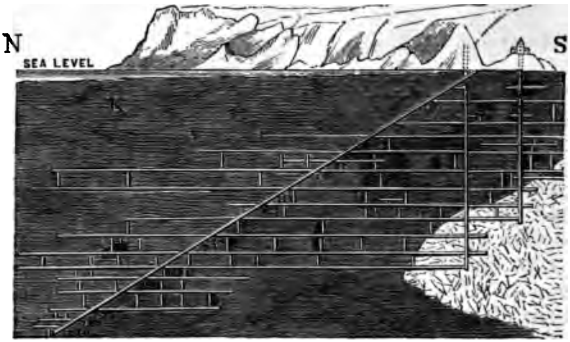

Fig. 12.—*Scale*, 160 fathoms to 1 inch.

45. The advantages of a downright shaft are—greater ease in sinking to a given depth, and facility for hauling or pumping. Its disadvantage is that, with inclined lodes—and the average inclination of Cornish lodes is 20° from the perpendicular—a considerable amount of cross-cutting is necessary at the different levels.

The chief advantage of an underlie shaft is, that it affords an opportunity of testing the lode in its neigh-

bourhood for the whole depth of the shaft, and in some instances the ore got from the shaft itself is more than sufficient to pay the expense of sinking it. Probably the best arrangement for an extensive mine will be to have one principal downright shaft, and several secondary underlie shafts.

46. Security of Shaft.—The shaft having been pegged out and excavated to the depth of a few feet, it is generally necessary to raise and secure its brace or mouth. The raising is, in low situations, important to prevent the entrance of surface water; and a neglect of such a precaution, to a sufficient extent, has occasionally been followed by the flooding of the mine, as was the case at East Wheal Rose Lead Mine in Cornwall some twenty years ago, when the bursting of a waterspout caused a small stream in the neighbourhood to overflow its banks, and the water getting down the shaft drowned a large number of men.

Another reason for raising the brace of the shaft is in order to secure a "tip" for the material excavated; and when the ground is level, and the shaft is intended to extend to a great depth, a considerable addition to the height of the "brace" will need to be made from time to time on this account.

47. Timbering.—In soft ground some support is necessary in all cases for the sides of the shaft; and in countries where easily wrought freestone or limestone is readily obtainable, no better plan than masonry can be adopted. In Cornwall the granites and elvans of the county have not unfrequently been employed with good effect in this way. It is still more common, however, to use timber, either that grown in the neighbourhood, or very frequently the fir of Norway. The brace is sometimes formed of a framework of thick balks bolted together. Sometimes the successive timbers of the shaft are hung to this by bars of iron, but very frequently the pressure of the "country" is sufficient to keep the timbers in their places.

For small and unimportant shafts in clay ground, the plan known as "covered" binding is frequently employed, but the more common and approved mode is to timber by "sets and laths."

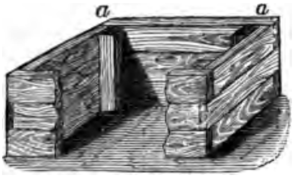

Fig. 13.—SETS OF COVERED BINDING. *Scale*, about 4 ft. to 1 in.

In the covered binding the different sets are made to rest upon each other as shown in figs. 13, 14. They are sometimes kept in place by corner timbers nailed in as shown at *a*, fig. 13, sometimes by notching the sets, sometimes by the mere pressure of the ground.

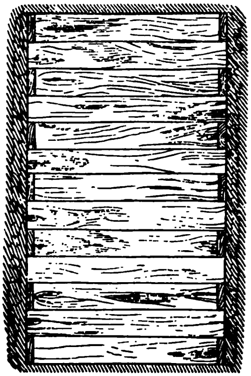

Fig. 14. — SHAFT TIMBERING, COVERED BINDING. *Scale*, 6 ft. to 1 in.

The method by sets and laths differs from this in the sets being much thicker and notched deeply together, and in their being placed at some distance, generally about 4 feet, apart. Sometimes short corner pieces called "studdles" are placed upright to keep the sets their proper distance apart, but this precaution is frequently omitted. The space between is strengthened by laths which may vary from 1″ to 3″ in thickness. This mode is shown in figs. 15, 16, where *a a* are the sets, *b b* the laths. The timbers which form the longer sides of the sets are called the wall plates, the shorter pieces are "end pieces." **Winzes** are usually much smaller than shafts, and rarely require timbering except in clay "country," when a kind of covered binding is sometimes put in.

48. Levels.—Levels are now rarely driven less than 6 ft.

high or 4 feet wide, often 8 feet high and 6 or 7 feet wide, especially in hard ground. The increased size is not only better for ventilation, but is rendered necessary by the almost universal use of tram-roads instead of wheel-barrows in modern mines. Levels should be driven as truly level as possible, especially when long, as, if the rise be great, ventilation is almost impossible. With a well laid tram-road, a fall of $\frac{1}{4}''$ to $\frac{1}{2}''$ in a fathom will be found sufficient. Levels very frequently need to be timbered more or less completely, and although covered binding is occasionally used, the method of sets and laths is far more frequent. When a level is driven by the side of a lode, one side only may need timbering in many instances.

Fig. 15.—Shaft Timbering. Timber "set." *Scale*, about 4 ft. to 1 in.

Fig. 16.—Shaft Timbering. Sets and Laths. *Scale*, 6 ft. to 1 in.

In fig. 17 the complete mode of timbering levels is shown; *a a* are the legs, *b* the cap, *c* the stretcher, *a*, *b*, and *c* together forming a "set." The laths are shown at *d*, *d d* being the side laths, *e* the "back laths." In less tender ground the stretcher at *c* is often omitted.

Fig. 18 shows the mode of timbering when one side and the roof only needs support. Many other modifications are used, varying with the exigencies of the occasion, the material at hand, and the ingenuity of the miner. Sometimes, instead of the timber "legs," a rough masonry composed of the debris of the workings, is resorted to, and occasionally this material is built into a complete arch, so

dispensing with timber altogether. In every case where timber is used, the bottom of the level should be made wider than the top or "back," as the strength of the "cap" rapidly decreases with every increase of its length, and it is towards the bottom of the level where width is most required.

Fig. 17.

Fig. 18.

49. Distance between Levels.—The most common distance between levels is now 10 fathoms, measured on the underlie of the lode, but 12 fathoms and 15 fathoms are sometimes left between. Formerly, many levels were driven only 5 fathoms apart. These various distances have all been adopted at Botallack mine, as shown in fig. 12.

Where the level meets the shaft, an enlargement is usually made; this is called a "plat." It is most useful as a place of deposit for the ore previous to its being sent up "to grass." With the gradual introduction of lifting cages, large plats will be less required, and will no doubt, in many cases, be dispensed with.

50. Tutwork.—Shafts are sunk and levels driven, in Cornwall and elsewhere, at a fixed rate per lineal fathom. Special agreements are made in each case, subject to modification at the end of the "take," which is mostly for one

or two months. This form of bargain is called "tut work."

The timbering, when necessary, is sometimes done by the miner as part of his bargain, and the excavated mineral is drawn to the surface at his cost. Deductions are also made from the gross amount of his earnings, for powder, candles, tools, etc., supplied to the men from the stores of the mine.

Sometimes, however, the timbering is done by special timbermen, and the excavated material is drawn to the surface at the cost of the employers. The prices of sinking and driving vary much according to the nature of the ground, depth from surface, size of shaft or level, and many other particulars; but some idea of the labour cost of such works may be gained from the following table of prices paid during the year 1873, within the direct knowledge of the writer.

51. For sinking shafts in soft "killas" or clay ground.

Near the surface, . . .	£2 to £3	per cubic fathom.
Below about 20 fathoms, . .	3 to 4	,, ,,

Sinking shafts in "compact killas," or "pick and gad" ground.

Near the surface, . . .	£4 to £6	per cubic fathom.
Below 20 fathoms, . . .	5 to 8	,, ,,

Sinking shafts in "fair blasting ground."

Near the surface, . . .	£6 to £20	per cubic fathom.
Below 20 fathoms, . . .	10 to 30	,, ,,

Levels about one-third cheaper for non-blasting, and one-half cheaper for blasting ground.

In extreme cases much higher prices have been paid, but these will suffice for the elementary student.

The shafts referred to varied from 8×6 to 12×9 feet, the levels from $6\frac{1}{2} \times 2\frac{1}{2}$ to 7×5. For more easy comparison the prices have been calculated to *cubic* instead of *lineal* fathoms.

Although large levels are, as a rule, to be recommended, in general there are cases in which very small levels may

be adopted with advantage. Thus, in the china clay districts of the centre of Cornwall, levels only 4′ or 5′ high, and 2′ 0″ to 2′ 6″ wide are occasionally driven in easy ground to explore the character of a bed of clay, or to serve as channels for water. When the ground is favourable, these small levels will often stand without any timber; and as they are not used for the transit of material after their completion, their small size is no disadvantage, while their economy of cost, as compared with larger levels, is very considerable. When the excavated material has not to be wheeled more than about 100 or 150 yards, such levels may often be driven at a total cost of from 8s. to 12s. per lineal fathom.

52. The timber used in Cornish mines is mostly Norwegian pine, and this costs, by the time it reaches the mines, about 1s. per cubic foot on an average. Supposing a shaft, therefore, 10 feet by 7 feet, inside measurement, to be fully timbered by the "sets and laths" mode, using timbers of about 9 inches thick for the sets, which are placed 4 feet apart, and laths of 1½ inches thick, the cost for timber will be about £3, 10s. per fathom of depth, including the cost of cutting out the timbers, and allowing for a little waste.

Such timbers in a shaft of the size specified would be suitable for soft and moderately heavy ground. The cost of sinking in such ground would be from £6 to £8 per fathom. The cost of the timbering would therefore be about one-half the labour cost.

For a level in similar ground 7 feet high, 3 feet 6 inches in the "cap," and 4 feet 6 inches at bottom, timbered with half-timber sets, and 1½ laths, the cost of driving will be about £2, 10s. to £3, and of timbering, £1, 5s. to £1, 10s., or again about half.

CHAPTER VII.

PRODUCTIVE WORK IN VEIN MINING.

53. In a well managed mine the deadwork will be kept well in advance of the stopes which yield the bulk of the ore. It is true that as the levels are usually driven, and the winzes sunk *on* the lode, or close to its foot-wall, some ore will be obtained, in most cases, during the progress of these works. Sometimes, indeed, the ore so obtained is more than sufficient to pay all the expense of such drivages. The bulk of the ore, however, is got out by the process of "stoping" between the levels in those portions which are judged sufficiently rich, that is, in the "bunches," or "shoots" of ore. Even in the richest mines these portions will form a comparatively small portion of the lode, and in poor mines the "bunches," as they are called, are few and far between.

54. Two totally different modes of stoping are in common use, called respectively "overhand" and "underhand" stoping.

In underhand stoping the ore is gradually worked away downwards from the floor of one level, the ore and deads being taken out through the level next below. This mode is illustrated in fig. 19. It is still adopted in some German, a few English, and many South American mines.

In the mines of Cornwall, underhand stoping has been mostly superseded by the more economical overhand mode. The ore is thus broken more cheaply, but more timber is required for the construction of platforms, upon which the men stand while at work, "stulls" as they are called. Usually, some at least of this timber is left to support the hanging wall of the lode, but sometimes it will stand of itself after the ore is worked out, or stuff may be brought

from the surface to fill in the vacant spaces or "gunnies." Occasionally, where the ore is not wanted immediately, much of it is left in the level for a time, to serve as a platform for the men while breaking away the ore in the "backs." Both modifications are shown in fig. 20.

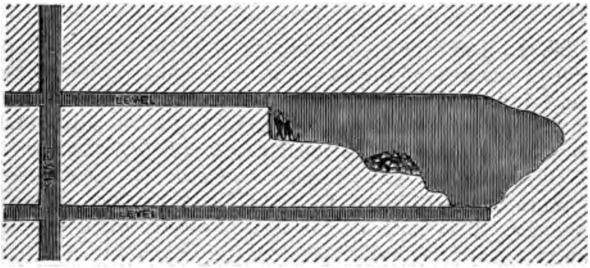

Fig. 19.—UNDERHAND STOPING.

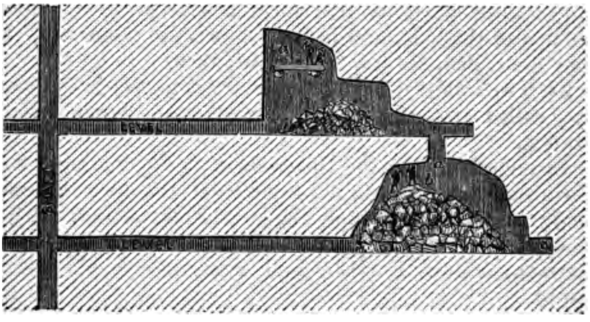

Fig. 20.—OVERHAND STOPING. At *a* men are working on a staging or "stull"; at *b*, men are at work standing on a pile of broken ore; *c*, *c*, are the ends; *d* is a "winze."

Sometimes the stopes are worked at a fixed rate per ton. This is a form of "tutwork," but it is sometimes called simply "stoping." In fair blasting ground the prices of stoping vary in Cornwall from 2s. 6d. to 5s., or

6s. per ton. In Somersetshire and South Wales the prices paid will be considerably higher.

55. Tribute Work.—Very often certain portions of the stopes are set to parties (called "pares") of "tributers," who engage to break the ore, and in some cases to pay all charges until it is ready for sale, for a certain proportion of its value, varying from a few pence in rich "pitches," to 15s. in the £ in poor pitches. A species of bidding takes place at "setting day" for all the pitches in the mine, both tutwork and tribute, and they are "set" to the lowest bidder, as a matter of course.

The tributers are generally the most skilful miners, and many valuable discoveries have been made by them.

56. The ore broken from the stopes and tribute pitches is wheeled or trammed along the levels to the shaft, and raised by appropriate machinery to the surface, as will be described in a future chapter.

The mode of driving and sinking by "tutwork" at a fixed rate per fathom works well, and it is very doubtful whether any better mode can be devised.

In poor stopes, where large quantities of ore of tolerably even quality have to be removed, payment at a fixed rate per ton is probably the best mode, the men being paid only for the merchantable ore sent to the surface.

Where the stuff varies much in quality, the mode of tributing will probably be the best, although it is a good deal gone out of use of late.

By this mode, as the men are paid a certain proportion on the value of the ore broken, it will be to their interest to separate the deads or the poor stuff from best work, as by long experience it is shown that the aggregate result will be to the advantage of the men when such a selection is made.

57. All the various modes of working require the most strict watchfulness and much judgment on the part of the captain or overlooker.

Tutwork men are continually allowing the shafts and levels to become crooked and small, the bottoms of the

levels to rise too rapidly, putting in faulty timbering, etc.

Stopers paid at per ton are always apt to send worthless material to the surface to increase their total yield. Tributers are likely to leave small portions of rich ore behind, or to bury it up with deads, where it would pay them better to break down ore in bulk. For these and other reasons, a captain needs to be continually on the watch, to visit every end and every stope continually, and to be aware of every change of ground as it occurs. He must also know, from practical experience, the amount of work which can be done in different kinds of ground, and accordingly underground captains are always most wisely selected from among those who have had experience as working miners.

CHAPTER VIII.

THE MINING OF BEDS AND IRREGULAR DEPOSITS.

58. THE mineral deposits known as "pipe-veins," "gash-veins," "carbonas," "pockets," and "flats" are often of considerable importance, but less so than the true "rake-veins" or lodes. Besides these, very important "beds" of ore occur in many districts lying parallel to the general stratification of the containing rocks.

Beds of iron ore of considerable thickness occur interstratified with beds of limestone and sandstone in the coal measures of the North of England, and in the oolitic rocks of Yorkshire and Northamptonshire. Beds of gravel containing particles of gold or of tin ore occur in the valleys of very many countries overlaid by superficial accumulations of alluvial matter.

59. The mode of working such beds differs much from that followed in the case of lodes, and must be here described. As types of such workings we shall briefly

explain the systems of working followed in the iron districts of Cleveland in Yorkshire, and in the tin-bearing gravels of Carnon Valley in Cornwall.

In vein mining trial borings are not often made, shallow trial pits being much cheaper, and generally being found sufficient.

In bed-mining, however, the system is—most properly—exceedingly common. These trial-borings are made as much as possible in a direct line across the "strike," or in the direction of the "dip" of the rocks, and closer together in disturbed than in undisturbed districts.

60. The preliminary examination will have given some information as to the depth to which the bore-holes will need to be carried. Special observations must, however, be directed to discover whether any "faults," "slips," "throws," or "troubles" exist in the neighbourhood of the proposed borings, as these may upset all calculations if not discovered in time. In some cases these faults throw the beds of ore down many fathoms, as shown in fig. 21. Generally, if one such fault is known in the district, others may be expected to occur parallel to it.

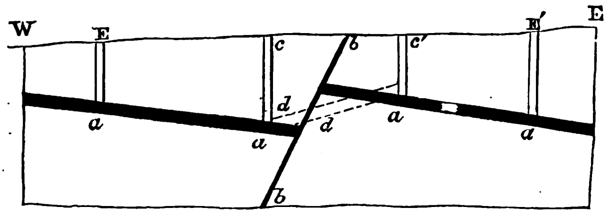

Fig. 21.—*a*, *a*, Bed of iron ore; *b*, *b*, fault; *c*, *c′*, *e*, *e′*, bore-holes.

The greater slips in the North of England coal field, for example, have more or less an east and west direction; in Lancashire, north and south; in South Wales, north-west and south-east. Minor slips occur in almost every direction, and one object of the trial borings is to determine their extent and position. In districts known to

be disturbed, it is therefore good policy to have very many bore-holes, as, otherwise, important dislocations of strata may not be discovered until much money has been spent in laying out useless or unsuitable works. A consideration of fig. 21 will show that the information to be derived from bore-holes may be seriously misunderstood if they be not sufficient in number. Here a bed of ore *a a a* is thrown by an unsuspected fault *b b*. It is plain that if bore-holes are only made at *c c* the bed will be supposed to have the inclination shown by the dotted lines *d d*, but if the additional trials at *e e* be made, the true position of the beds will be at once known.

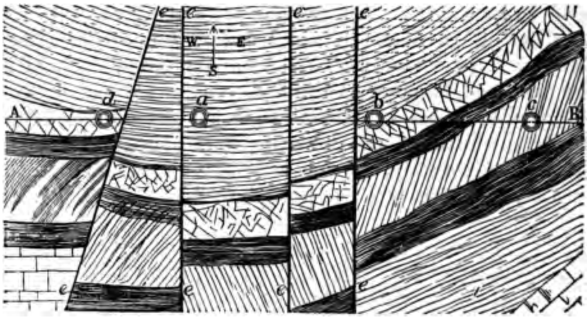

Fig. 22.—*a, b, c, d*, shafts; *e,e*, faults; A, B, line of section in fig. 23.

Figs. 22 and 23 show a series of faults in plan and section—A B, fig. 23, being a line of section on A B, fig. 22. The metalliferous miner will see that the faults are much like the lodes with which he is familiar, differing only in their contents. In the coal measures these faults do not contain ores of tin, and but seldom those of copper, but they frequently yield those of lead or iron. The great Minera lead vein is a fault which differs in no essential particular from the faults common in most bed-mining districts.

61. Trial-Borings are usually carried out by contractors

who provide their own skilled workmen, boring tools, and special plant, the mine-owners finding engine or water-power, and, frequently, labourers.

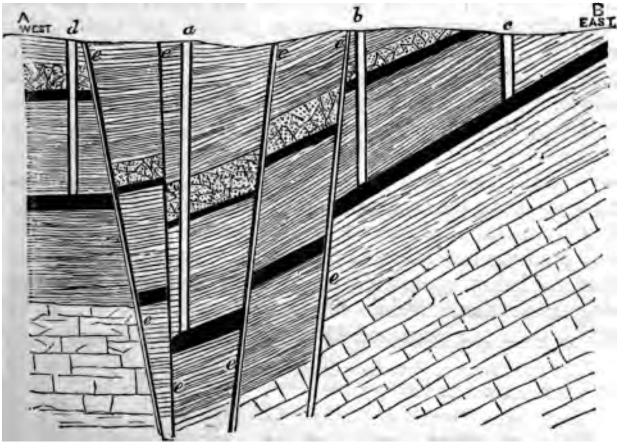

Fig. 23.—Section on line A, B, fig. 22; *a, b, c, d,* shafts; *e,e,* faults.

The boring tools are sometimes worked simply by a rope passed over a shearlegs or triangle, and then round a "jack-roll" or windlass, but for deeper holes special boring machines have been invented, among which "Kind's" and "Mather and Platt's" hold prominent places. The boring tools are so contrived as to bring up from time to time portions of the bottom for examination. To prevent the sides of the hole from falling in it is often necessary to line it with metal tubes.

62. Cost of Boring.—The cost of boring at Newcastle, in 1869, was—

For the first five fathoms, .	. 7s. 6d.	per fathom.
" second " .	. . 15s. 0d.	"
" third " .	£1, 2s. 6d.	"

and so on, increasing 7s. 6d. per fathom on attaining each complete 5 fathoms.

These charges were for boring through ordinary sandstone and other soft rocks. For hard limestone, basalt, or other rocks of unusual hardness, or for holes of unusual depth, special agreements are made, the charges sometimes amounting to many pounds per foot. The cost of such bore-holes is very great, but the precision and accuracy thereby secured in laying out permanent works renders it well worth while to incur the expense.

Major Beaumont's patent Diamond Borer has recently come largely into use for trial borings, and it makes its way with great facility through every kind of rock, and in very many cases the saving of time and money resulting from its employment is very great. All bore-holes are paid for according to the depth, the portion near the surface being completed at a much less cost than the deeper portion. Prices for boring in South Wales, in 1873, with the Diamond Borer were as follows:—

In the lower coal measures and millstone grit,

For the first 100 feet,	. .	9s. 6d. per foot.
,, second ,,	. .	13s. 6d. ,,
,, third ,,	. .	17s. 6d. ,,

and so on, increasing 4s. per foot after attaining each 100 feet. These prices are for bringing up a 1″ core. Some additional charges are made for fixing head-gear, etc.

63. Position of Shaft.—Having at length determined the depth and dip of the ore bed, the miner will be in a position to lay out his principal shaft or shafts. When the ore lies as in fig. 21, the shafts would be better sunk at *c e′* than *c′ e*. These positions are chosen in order that the ores may descend to the bottom of the shaft by their own weight, to save the expense of horse or engine power. The sinking of the shaft will not differ much from the same operation in metal mining, except that it will sometimes be circular instead of rectangular, and always vertical instead of inclined. In bed mining for iron ore the workings will seldom be very deep, except when the ore is worked in connection with, and subordinate to, the working of coal, so that ordinarily, the

shafts not being deep, no great engineering difficulties are experienced in sinking them.

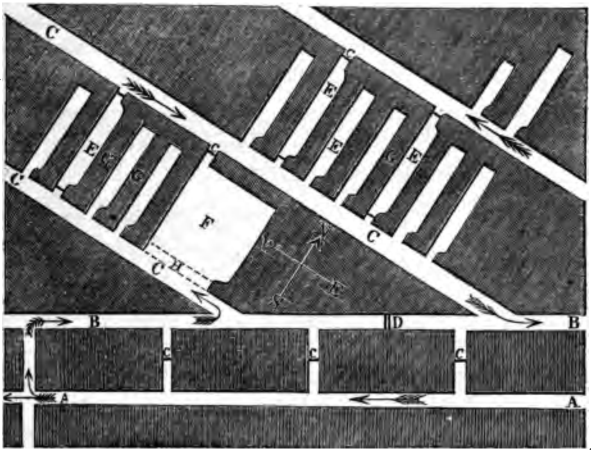

Fig. 24.—AA, BB, Main levels; CC, headways; D, regulating door; E_2E, bords; GG, pillars; H, pack wall to keep heading open; *c*, air stoppings.

For shallow workings, where the ore is not too much hardened by a great weight of rock above, the mode adopted many years ago by Mr. Bewick at Grosmont may be recommended, as illustrated in fig. 24. A pair of levels A A, B B are driven into the hill from the lowest point attainable towards the boundary of the property. These levels may be about 6 feet wide and 8 feet high. From one of these levels headings C C are driven, following the principal heads or "joints" of the ore, about 22 fathoms apart, and 8 feet wide: of course the angles which these headings make with the levels will vary in different mines. From these headings the bords E E are opened from 4 to 6 fathoms apart, widening out as they leave the heading, so dividing the ore into pillars averaging 5

fathoms by 40 fathoms. These are occasionally holed into the next heading. The pillars are removed by cutting away sometimes the end towards the rise, sometimes the middle or lower end, according to circumstances, timber being used to support the roof while the men are so engaged. Fig. 25 shows one mode of removing pillars.

Fig. 25.—Showing Mode of Removing Pillars in Iron Mining.

With skilful workmen and a favourable roof very little danger is to be apprehended, and very little timber will be lost.

64. In deeper workings it is desirable, from the greater compactness of the ore, to lessen the proportions of "narrow work," as the headings are called, leaving the pillars much larger, or else clearing a long face of work at one and the same time, as will be more fully described in the treatise on coal mining.

The cost of getting ore will vary according to the thickness of the bed, the hardness or compactness of the ore, and other particulars, from 1s. to 2s. 6d. per ton in the headings, and from 9d. to 1s. 6d. per ton from the pillars. Very often the headings are driven at an agreed price per fathom in length, which may vary from £1 to £3 per fathom, exclusive of the cost of timber and haulage.

65. Alluvial Mining.—In working alluvial beds, which are too deeply situated to be worked in the open as described in the next chapter, a kind of bed mining very

similar to that just described is frequently adopted. Shafts are sunk until the ore-ground is reached; levels are driven for the most part in the orey stratum, and supported by timber; the ore is gradually worked away, the timber withdrawn, and the roof allowed to subside.

When the ore-ground lies near the surface, and the ground above is dry, but little difficulty is experienced; but if the overburden is thick and wet, and especially if the ore-ground should pass under the bed of a stream or under the sea, the work is often one of great difficulty.

At the Restronguet Tin Stream Works in Cornwall, a bed of tin-bearing gravel occurs under a creek of Falmouth Harbour, beneath about 10 feet of water at low tide, and about 60 feet of mud. This mud is covered at high water with about 20 feet of water.

66. Trial borings were in the first instance made 3 inches diameter, by which the thickness and quality of the tin gravel were approximately determined. A shaft was then sunk on the shore to a depth of 18 fathoms, and from this a deep level was driven towards and under another shaft which was made of iron and sunk in the bed of the estuary. A tramroad was then laid in this level 2½ feet above its floor, by which the ore was brought out. The space underneath serves as a water channel and standage or sump.

67. The iron shaft consists of cylinders of cast iron 6 feet diameter, 6 feet long, and 1¼ inches thick, with internal flanges faced in a lathe. Each length weighed 2½ tons, and was lowered by a crane through an opening in a timber stage between guides to its true position. The bottom length was made sharp, and weights were placed on the upper lengths until the true bed was reached—the greatest weight at any one time being 250 tons.

The shaft is continued through and below the tin bed as a timbered excavation—leaving two openings opposite each other. A level is driven from these, bearing north-east and south-west, to prove the extent of the tin

bed. From these two other levels are driven up the creek in a north-westerly direction—as shown at E E in fig. 26, which is a plan and section of the workings—each having a tramroad laid in it. Air levels are driven at right angles to these as far as the tin bed is productive. The ore is got out by a kind of long-wall method called "stripping," at J J—wheeled back to the main levels—tramed to the "passes" F F, communicating with the deep level A A, where it is shot into the waggons waiting below to receive it. Thence it is conveyed to the bottom of the land shaft and raised in cages to the surface.

68. The tin gravel varies in thickness from 3 inches to 7 feet, averaging, perhaps, 5 feet; the produce in oxide of tin varying from 15 per cent. to ·1 per cent. All the levels need strong timbering to resist the crush of the overlying mud. In the principal levels this consists of "sets" of Norway timber 8″ thick for the legs and 10″ in the cap. These legs are 4½ feet apart at bottom, 7 feet long, and 2½ feet apart at top. The sets are placed every 2½ feet in the level, and covered in with "half-timbers" over the caps, and "laths" 1½ inches thick at the sides. The cost of driving the main levels is about £3 to £5 per fathom. The tin gravel is "stripped" at a cost of 3s. to 6s. per ton.

A width of 30 feet of gravel is left on each side of the main levels to keep them open.

The working of irregular deposits of ore varies much in different districts, but all the modes are modifications of the systems employed in vein mining and bed mining, so that no special descriotion is necessary

CHAPTER IX.

ON OPEN WORKS AND HYDRAULIC MINING.

69. In most mining countries, and especially in countries yielding tin ore and gold, these minerals are

found not only in veins or deposits, but also as small pebbles or grains scattered through the detrital matter or alluvium which occupies the valleys. Such alluvium also contains diamonds and other precious stones in Brazil and South Africa, where the mode of working adopted is very similar to that by which the stream tin or alluvial gold are obtained. The deposit of tin gravel at the mouth of the Carnon Valley is illustrated in fig. 26, but the overlying mud, and the situation in a creek of Falmouth Harbour, make it necessary to work it here by mining, as described in the last chapter. The same deposit, however, higher up the valley, as well as many similar ones, have been frequently worked in the open by removing the over-burden entirely, so laying bare the tin ground.

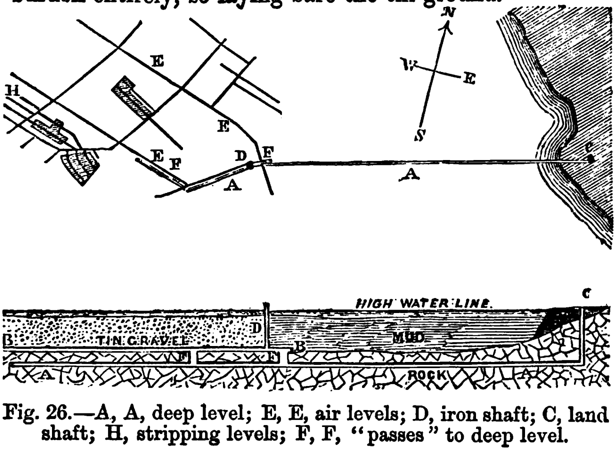

Fig. 26.—A, A, deep level; E, E, air levels; D, iron shaft; C, land shaft; H, stripping levels; F, F, "passes" to deep level.

70. Mode of Working.—The most advantageous mode of working is to clear the over-burden away completely from a good sized space, remove the ore-ground for subsequent treatment, or treat it on the spot, and then to fill up the space with the over-burden from the next section. In this manner no part of the over-burden has to be removed to a great distance, nor yet to be

lifted to any considerable height; and the cost of removal will lie between 2s. and 5s. per cubic fathom. Even coal is sometimes thus obtained from open workings in South Wales, where they are called "patch" works.

71. Hydraulic Mining.—In California, Nevada, and elsewhere, very large deposits of sandstone rock occur which contain a small but paying proportion of gold. These rocks are sometimes hard, and need to be stamped to a fine powder before the gold or tin ore can be extracted, but often they are so far decomposed that they may be washed down by a jet of water directed with force upon the face. The water is stored in reservoirs at a considerable elevation, and brought to the works in flumes from great distances. In this manner a pressure of 100 to 200 lbs. per square inch is often obtainable, and with such a jet from a 12″ to 20″ pipe, and a nozzle from 4″ to 8″, a man is able to wash down the rock at a cost of from 1d. to 2d. per ton. The same water serves for the subsequent dressing operations, and the total working cost is so slight that stuff containing no more than fourpenny worth of gold per ton is, when soft, workable at a profit. This is the so-called hydraulic mining.

In Cornwall a good deal of tin ore is obtained from both the granite and slate, especially in the centre of the county, by open working. A produce of from 3 lbs. to 9 lbs. of saleable tin ore per ton of stuff is found sufficient to pay all expenses and to leave a considerable profit, and, under favourable circumstances, the author has known 2 lbs. per ton to yield a profit. The oxide of tin occurs in the joints of the rocks in very thin layers, and it is necessary to break down the rock and crush and "dress" it *en masse* in order to obtain the "black tin." At Minear Downs, near St. Austell, the ore occurs in a soft killas, and one man is able to break down from 7 to 8 tons per day; at Mulberry Hill, near Bodmin, which is also killas, from 5 to 6 tons. Nearly all the work in these two places is effected by the pick and gad—blasting being rarely necessary. At Rock Tin Mine,

near St. Austell, a large open quarry is worked for tin in a very hard schorlaceous rock. Here the average produce is about 8 to 9 lbs. per ton of stuff, and each man can break down from $1\frac{1}{2}$ to 2 tons per day. The rock in this quarry requires frequent blasting.

72. China Clay.—In very many parts of Cornwall, and in Devonshire, a peculiar kind of white granite is so completely decomposed as to be quite soft, the felspar being converted into kaolin or China clay. A common mode of working this is to bring a stream of water over the face, which is guided hither and thither by a man who uses a pick to assist the water in bringing down the rock. In this manner one man can often bring down from 12 to 20 tons of rock per day. It is probable that the use of a powerful jet as described above would enable him to double these quantities at least.

73. For all these operations it is necessary to remove the "over-burden." The circumstances of working will vary much in different works. On a hill side the burden may be removed cheaper than on level ground—a deep over-burden cheaper in proportion to its depth than a shallow one, etc. Sometimes the over-burden will be so soft and regular in composition that a pick is hardly necessary, at others it will be very hard and firm, or mingled with stones, large and small, and all these circumstances will affect the cost of removal. In general, however, if the stuff may be stored at moderate distances without being much raised, and if proper tramroads be provided, the cost will not be likely to fall under 2s. nor to exceed 5s. per cubic fathom. In cases, however, where large rocks occur which need to be blasted, the cost of blasting must be added.

74. Blasting.—The process of blasting deserves careful study from every one engaged in mining operations, whether in open works or underground. It is, of course, to be learnt by practice only, but some few general remarks will no doubt be useful. The process in outline is as follows:—A hole is first made in the rock by means

of the mallet and borer (these tools will be described in the next chapter). In general one man holds the borer while it is struck or "beaten" by one, two, or three strikers, who deliver heavy blows alternately upon its head, the holder giving it about one-eighth of a turn after every blow. A little water is fed into the hole from time to time, and at intervals the "sludge" is withdrawn from the hole by means of a "swab-stick." In this way a hole is bored from 1 inch to 2 inches in diameter at the rate of from 4 to 30 inches per hour, according to the hardness of the rock. In the extreme west of Cornwall, at St. Just, a small borer is used which is held in the miner's left hand—the thumb and little finger below, the other fingers above the borer—and struck with a light hammer held in the right hand.

In quarry work a "jumper" is occasionally used, but very rarely by miners.

Of late years boring machines, working by steam or by compressed air, have been introduced for the purpose of boring these "shot-holes," as they are termed, but hitherto they have not proved very successful underground, although they have done good service in driving large tunnels, in sinking shafts, and in open quarry work.

The hole being bored to its proper depth, a quantity of gunpowder is placed in it,—a piece of safety fuse long enough to reach the powder is placed in the hole, and it is filled up with hard clay, sand, broken brick, or other tamping material, which is driven in firmly with the tamping bar. This was formerly done with an iron bar, when the operation was very dangerous, but it is illegal now to use any other than a copper or copper-tipped bar, and accidents while tamping are of comparatively rare occurrence.

75. Sometimes gun-cotton, nitro-glycerine, or dynamite are used instead of gunpowder, when tamping becomes less necessary, or even altogether needless. These explosives are especially valuable in wet places, and for blasting loose rocks.

76. The hole having been charged, the outer end of the fuse is set on fire, the workmen retire to a safe place, and, when the fire reaches the powder or other material used, it explodes with great violence. In general, the holes need not be so large nor so deep for dynamite, gun-cotton, or nitro-glycerine as for gunpowder, and they are usually larger in open workings than underground.

77. The miner should so place his hole that it may encounter as nearly as possible an equal resistance in every direction, and much practice, observation, and judgment will be needed before he will be able properly to apportion the charge to the amount of work to be done. He must have a keen eye for "vughs," "joints," and "breast-heads." In some cases it will be an advantage to introduce the powder or other explosive in a cartridge form, especially in wet or loose ground.

CHAPTER X.

OF THE TOOLS USED IN BREAKING ROCK.

78. The principal tools used by miners in "breaking ground," as it is termed, are pick-axes or "picks," "pikes," "hacks," "slitters," or "mandrils," as they are variously called, of different kinds; hammers or "sledges," of different forms and weights; shovels; wedges or "gads," and "moyles;" borers or "boryers."

79. Besides these we may mention such miscellaneous tools as "tamping bars," "prickers," "swab-sticks," hatchets or "dags," adzes, saws, and other tools used for blasting, timbering, and other special purposes. All these vary considerably in form, size, and other particulars in different districts, and when used for different purposes. We can only describe here the principal varieties.

80. **Picks.**—These are mostly made of iron, with points or "tips" of steel, while the handle, "helve," or

"hilt" is formed of ash or hickory. In the metal mines of the West of England the picks are usually of the form shown in fig. 27, which is called the "poll-pick," having its head or "pane" *a* steeled as well as its point. This is the most useful tool the miner has, as it serves as a hammer as well as a pick. It is also very much used as a lever, the curve of the pick serving as a fulcrum, and great leverage being obtained through the handle or "hilt." It is also much used as a hammer to drive the "gad," an instrument presently to be described. A fair length is about 15 inches, the weight is about 4 lbs., but they are made occasionally but little over 2 lbs., and sometimes as much as 7 lbs. or even 10 lbs. The heaviest picks in Cornwall are used in the China clay pits of the centre of the county.

Picks of very similar form are used in the lead mines of Derbyshire and Wales.

When the pick is much used as a lever, the head is frequently formed as in fig. 28*a*, with a projecting wing to afford increased support to the helve. This is called a jackass pick. Similar support is better afforded by making the eye portion of the pick somewhat deeper than usual.

Ordinarily, for hard ground, the point is sharpened four-square, but for soft ground it is usually flattened, and for clay ground it is frequently spread out to a width of $1\frac{1}{2}''$ or $2''$, as in fig. 28*b*.

Fig. 29 shows a form of pick frequently used in the iron mines of Somerset and Wales, weighing from 4 to 5 lbs. A very similar form, but made somewhat slighter, and weighing only 2 or 3 lbs., is used in the coal mines of South Wales. For sinking purposes they are made much heavier, often 7 lbs., when they are known as "hacks" in some parts. These are often 18 to 22 inches long.

Helves of picks vary from 24 inches long in some poll-picks used in confined places, to 36 inches or more. *Many other forms* of pick are in common use, almost

every district having its own special form. The cost of a poll-pick of 4½ lbs. weight, the poll and tip well steeled, is in Cornwall at present about 2s. 6d.; the cost of the helve or "hilt" is 4d.

81. Hammers.—The chief kinds used in metal mines are mallets or "malls," used for "beating the borer;" "sledges," for breaking up large masses of rock, and for driving the "gad;" and "cobbing" and "spalling hammers" for further reducing the ore; "lath sledges" are used for driving the laths in ground requiring timbering.

The head or "pane" is usually steeled, the handle or "hilt" is made of ash or hickory. The "eye" is occasionally round, sometimes square, more usually, and much better, oval. Fig. 30 represents the "cat-head" mallet, used for "beating the borer" in many parts of Cornwall. It varies in weight from 4 to 9 lbs.—averaging, perhaps, 6 lbs. or 7 lbs. Fig. 31 is a "bloat-head" hammer used for single-handed boring in the extreme west of England, at St. Just. It weighs from 2½ to 4 lbs. The hilts of these single-handed boring hammers are rarely so much as 18″ long, but those for double-handed hammers are from 24 inches to 30 inches in length.

These boring sledges are sometimes used for driving wedges or "gads," and the poll-pick is also largely used for this purpose. Sometimes a special "gad sledge" is provided for the purpose. It is much like that already figured, but longer in the head and narrower in the pane, and weighs about 7 or 8 lbs. The form shown in fig. 32 is used for breaking up large rocks, but in this case the weight is often increased to 15 lbs., 20 lbs., or even more. These are sometimes called lump sledges.

Fig. 33 represents a "lath-sledge," for driving the "laths" used in timbering tender ground in Cornwall and elsewhere.

Fig. 34 shows a "spalling hammer" in common use, the weight will be from 3 to 6 lbs.

82. Shovels or Spades.—These also vary much in form and size. Fig. 35 represents the long-handled shovel,

used almost universally throughout the west of England not only for removing loose material underground, but also for general use at the surface. The "plate" is from 8 inches to 12 inches wide, and 10 to 15 inches long, slightly hollowed, and strengthened with a central rib extending about half way down. The point is often, and with great advantage, steeled. The handle or "hilt" is from 4 to 5 feet long in general, slightly curved. The weight of the plate is from 3 to 4 lbs; the cost, unsteeled, from 2s. to 3s., steeling about 6d. extra.

A shovel like fig. 36 is much used in the iron mines of the North of England.

The proper use of the long-handled shovel of the West of England is not very easily acquired; nor is it, perhaps, so well adapted for removing very light and loose material as the shorter handled shovels. For rough and coarse materials, however, its value cannot be over-estimated, as the point makes its way readily beneath or between the masses, and the knee serves as a fulcrum at the same time for the long lever handle.

The vanning shovel, used in "vanning" tin and other ores, is somewhat like fig. 35, but larger, rounded at the ends, and without the strengthening rib. It is made of very thin iron, so as not to exceed 2 or 2½ lbs. in weight. The plate may be about 15″ long; the handle about 3 feet. Much attention is paid so as to secure a proper curve for both plate and handle, as much of the success of the operation depends upon these particulars.

83. Wedges.—These are largely used for breaking down portions of rock, being driven by the poll-picks or hammers already mentioned. In Cornwall the wedges most commonly used are known as "gads," "pickers," and "moyles" or mules. The *gads* are usually made of steel, vary from 6 inches to 10 inches in length, and weigh from 1 to 5 or 6 lbs. Fig. 36 shows a very useful form. The *pickers* used in the Western mines are longer and narrower. They are used, as the name implies, to *pick out the small* fragments of loose rock which wedge

Fig. 27.

Fig. 28.

Fig. 29.

Fig. 30.

Fig. 31.

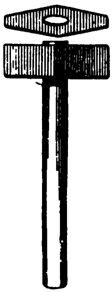

Fig. 32.

Fig. 33.

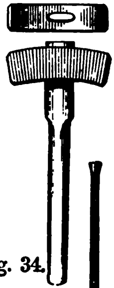

Fig. 34.

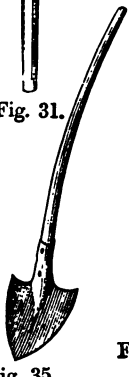

Fig. 35.

Fig. 36.

Fig. 37.

Fig. 38.

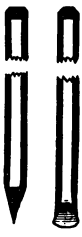

Fig. 39.

Fig. 40.

in larger portions in some situations. Worn out steel borers make excellent gads and pickers.

In Saxony it is common to make the gads with an eye in the centre, as shown in fig. 37. The miner passes a string through the holes, and so carries a day's supply without inconvenience. The larger kinds of wedges known in Cornwall as "moyles" are used more especially in quarry work. They vary from 10 inches to 18 inches in length, and weigh from 7 to 20 lbs. They are sometimes formed of iron throughout, but preferably with a steel tip. The term gad is sometimes restricted to those which are brought to a point, those having a chisel edge are more properly termed wedges. The cost of steel wedges varies much from time to time, but at the present time is about 8d. per lb. Iron wedges cost rather less than half this amount.

84. **Borers.**—These are often called "striking borers," "drills," "bits," and sometimes "augurs." Of course they are very different to true augurs.

Ordinary borers are worked by percussion, as described on page 58, borers which revolve under pressure are seldom used in mining operations, except for deep trial borings.

The borers used in metal mining are mostly of the form shown in fig. 39, varying in width from 1½ inches down to 1 inch, and in length from 1 foot to 4 feet,—the shorter being wider than the longer ones, in order to afford "clearance" as they succeed each other in boring deep holes. In open quarry work much longer and larger borers are used. In the west of Cornwall, at St. Just, the borers are lighter and smaller than elsewhere, single-handed boring being common as already mentioned. The best borers are made of steel throughout, but sometimes iron borers with steel tips are still used. For boring machines, the form of the cutting edge is very different from that shown in the figure—the chief forms being the "Z" and the "X." The jumper shown in fig. 40 is used in open quarry work, but not often by miners.

It is sharpened and steeled at both ends, and is held by the lump in the middle.

85. Miscellaneous Tools.—The *tamping bar* is a bar of iron tipped with copper, or a rod of hard wood, used for ramming home a "tamping" of clay or earthy material so as to confine the gunpowder or other explosive in a bore-hole to increase its useful effect. The *pricker* was formerly much used to make a hole through the tamping, but since the invention of safety fuse it has gone very generally out of use, the tamping being now rammed around the fuse itself.

Swab-sticks are rods of wood, with the fibres of the end beaten loose, used for drawing wet mud or sludge out of a bore-hole. Sometimes a kind of syringe known as a gun is used with good effect for this purpose.

A hatchet or "dag" is very useful in preparing timber for tender ground, and in Cornwall the miners are expected to be expert in its use, and also in the use of a cross-cut saw, hand saw, adze, and augur.

CHAPTER XII.

ON DEAD WORK IN SHAFTS, ETC.

86. THE shafts for metal mines, besides the actual labour of excavating, require much additional attention before they are ready for daily use. Some shafts are intended for pumping only; some for pumping and raising ore; and many for the use of the miners in proceeding to and from their work in addition to these objects.

87. Protection from Danger.—As the shaft reaches a depth of 10 to 20 fathoms, it is usual—or at least proper—to protect the men working in the bottom from the danger arising from the occasional fall of stones or materials, since a very small stone falling upwards of 60 feet is sufficient to cause death. A portion of the

shaft is covered over by a temporary sloping roof of boards called a "penthouse," as shown in fig. 41, and the men retire beneath this whenever anything is being raised or let down in the shaft.

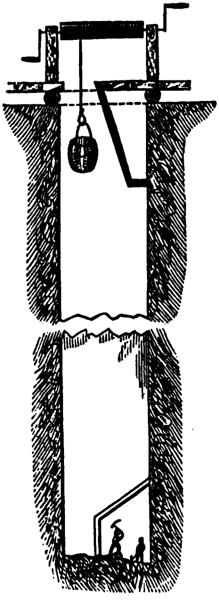

Fig. 41.

88. **Striking Deals.**—To diminish the risk of accident from the upsetting of the kibbles, what are known as "striking deals" are used in some places. These are pieces of wood placed as shown in fig. 41, which serve to guide the ascending kibble through the opening at the top of the shaft. Fig. 42 is a plan of a shaft divided for pumping and "winding," or "drawing stuff," with a narrow central division for a ladder-way. The winding division *a* is boarded in entirely from the ladder-way *b*, but the portion *c*, containing the pumps *dd*, is only separated at intervals from the ladder-way.

89. **Ladders.**—The ladders are usually made from 20 to 30 feet long. The "rungs" or "staves"—preferably 10″, but sometimes 12″ apart—are best made of iron bars let into the wooden sides, as shown in fig. 43. At the top and bottom, and at intervals throughout the length, longer bars *cc* pass quite through the sides, and are secured by a "cotter" as at *d*, or by a nut as at *e*.

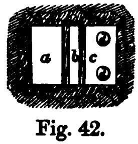

Fig. 42.

The ladders are placed in the shaft as shown in figs. 44, 45, of which fig. 44 represents the safest mode, as the manholes *bb*, in the "sollars" *aa*, are under the ladders. When the ladders are placed as in fig. 45, a careless stepper

may step back into the man-hole, and losing his hold on the ladder, may "fall away." Sometimes the man-holes are protected by trap-doors, but this leads to much delay, so that in practice they are seldom kept shut.

90. Partings.—The partings of the shafts consist of strong beams of wood, which either rest upon the timber "sets" of the shaft, or, in hard ground, are let into the country on either side; longitudinal timbers are nailed to these so as to form the shaft parting, and the same cross timbers serve to support the sollars.

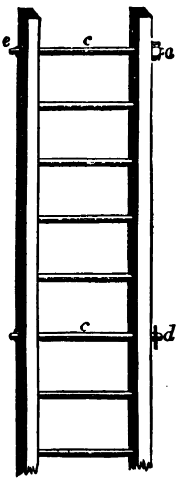

Fig. 43.

In the great majority of the Cornish metal mines, and in many of those of South Wales and the North of England, the men go to and from their work by means of the ladder-ways just described. The going down is not very hard work, but, as the average daily amount of climbing is, perhaps, from 400 to 600 feet, and *sometimes* as much as 1500, and as the men have frequently to bring up some of their tools for sharpening, the labour becomes very severe—as much in some instances as the whole of the work underground. In some mines the men are raised in the cages or skips used for raising ore, and this practice is increasing with the increasing use of wire-rope.

91. Safety Catch.—Sometimes the cages are fitted with safety catches which are intended to prevent the fall of the cage in case of the ropes breaking. One very convenient form of this contrivance consists of a strong spring which serves as the connection between the rope and the cage. The weight of the loaded cage keeps this spring bent, but if the rope should break it is at once relaxed, and, by its recoil, sets free some strong teeth, which immediately force themselves into the shaft railway or guides, and so

keep the cage from falling. But all such contrivances are liable to get out of order unless constantly watched; and as it is difficult to induce men to prepare for a danger which seems very remote, many practical miners prefer to do without all such appliances, and to trust entirely to the perfection of the rope, which is constantly under the inspection of the manager or his appointed agent.

Fig. 44.

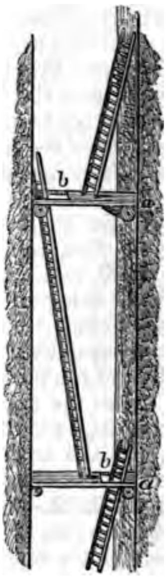

Fig. 45.

92. From shallow depths, or while sinking, the men are often raised by means of the rope used for raising the "deads." The writer has been frequently brought up from a depth of between 30 and 40 fathoms standing

with one foot in the kibble and holding on to the rope with his left hand; but such a mode cannot be recommended for depths of more than a few fathoms, especially if the rope is at all worn.

93. **The Man-Engine.**—In some of the larger Cornish mines the contrivance known as the "man-engine" is used for raising and lowering the men—a special shaft being devoted to this purpose, except that a ladder-way is also placed in the shaft.

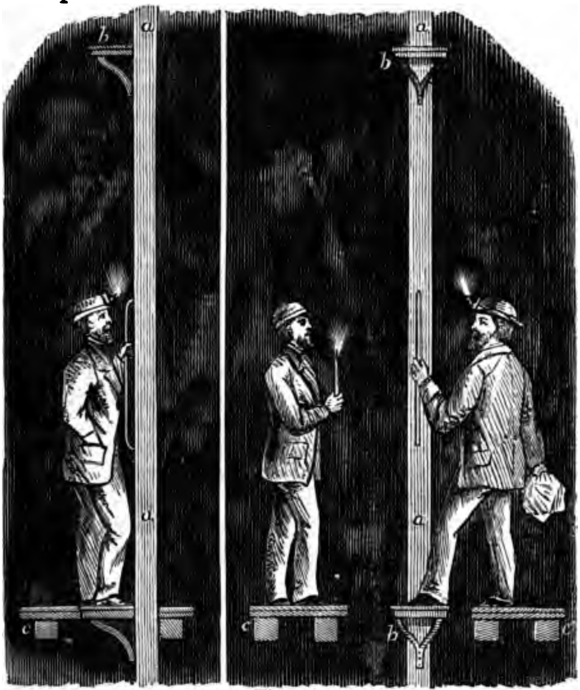

Fig. 46.

The man-engine consists of a beam of wood called the

"rod," *a a*, fig. 46, which is made to move up and down alternately through a space of twelve feet, by means of an engine devoted partially or entirely to that purpose. On the rod, at *b b*, steps are fixed twelve feet apart, on which the men stand while it is in motion, holding on by iron handles provided for that purpose. When it stops for an instant before the motion is reversed the steps are level with the "sollars," which are placed in the sides of the shaft. It is evident that if the men who stand on the steps during the upward motion of the rod step on to the sollars during its downward motion, and step back to the rod when it again rises, they will be raised to the surface by successive lifts of twelve feet, without any labour on their part except the stepping off and on. As many men may thus be brought up from their work at one time as there are steps on the rod, and, as the sollars are fixed on both sides of the shaft, an equal number of men may be carried down at the same time, each stepping on the rod as the man leaving work steps off. The weight of the rods, with all connections, averages about 25 cwt. per fathom; or for a depth of 200 fathoms amounts to about 250 tons. The great weight is balanced by several of the "balance bobs" to be described hereafter.

The man-engine is so great an advantage to all concerned—both workmen and employers—that it would soon become generally used in deep mines unprovided with lifting cages but for its great expense. This is very great indeed, since most of the shafts in deep and therefore old mines are too narrow and irregular to allow of its introduction without a good deal of expense in cutting down the irregularities. Still, in large mines, the expense is well repaid by the advantage.

94. The cost of supplying a man-engine, with driving engine, complete, to a depth of 200 fathoms—exclusive of the cost of the shaft itself—cannot be taken at less than £2000 to £2500. The interest on the larger sum at 5 per cent., with 10 per cent. added for depreciation of plant and repairs, amounts to £375 per annum.

The cost of coal and attendance for driving the engine, for oil, grease, etc., will amount to, say, £250 per annum in addition.

The labour of climbing from an average depth of 100 fathoms cannot be taken at less than 1 hour daily, or, with 3 shifts of 50 men at an average of 5d., the amount lost by climbing will be each day 62s. 6d.; or, for a year of 240 working days, say, £801, showing a clear gain of £175. For a depth of 310 fathoms the advantage is many times greater, since the exhaustion of the men from the labour of climbing and the time occupied will increase in a geometrical ratio. However, setting aside all calculations of cost, it is only necessary to look at the men who have just come up by ladders from deep mines to see that some mode of relieving them from such excessive toil is most necessary.

The man-engine originated in Germany, where it is called the "fahr-kunst." The idea occurred to some of the German miners, who saw the reciprocating action of the pump rods, to attach steps to it, and this was actually carried into practice. In Cornwall the idea of a man-engine was first carried into effect by Mr. Loam, in 1835, at Tresavean mine in Gwennap, Cornwall, and an award of £500 was made to Mr. Loam for this great boon to the working miners by the Royal Cornwall Polytechnic Society.

CHAPTER XIII.

ON THE CONVEYANCE AND RAISING OF STUFF.

95. The earliest mode of bringing the ore and deads from the "pitch," or place of work, to the surface, was probably by carrying it in baskets of wicker-work, and this mode is still in use in many foreign mines. For centuries, however, the mode most usually adopted has

been to place it in wheel-barrows, and to wheel it along the levels. In many metal mines this mode is still the only one in use, but some form of tram-waggon is now very generally introduced.

96. The first improvement was to lay planks along the rough floor of the level, upon which the wheel of the barrow would run more easily. The wheel-barrow used for such purposes in Cornwall is shown in fig. 47. It has no legs; is nearly parallel lengthwise; and its sides are but little inclined. Its ordinary load is about 1 cwt. to 1¼ cwt. It is usually made on the mine, and its cost varies from 8s. 6d. with a wooden wheel, to 12s. 6d. with an iron wheel. Such a wheel-barrow is admirably adapted for use underground in the old-fashioned narrow levels, and it is far more convenient for tipping sideways than is the ordinary navvy barrow, with wide sloping sides and long legs.

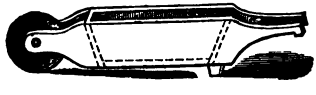

Fig. 47.

97. Tram-Waggons.—The introduction of a wider system of levels, and their increased length, due to the smaller number of shafts in deep mines, has led to the gradual introduction of tram-waggons, running upon four wheels. These are sometimes made of wood strengthened with iron bands, but are better of iron throughout. Fig. 48 shows a waggon made of boiler-plate. This, when 42 inches long, 30 inches wide, and 18 to 20 inches deep, will hold about a ton of iron ore; will weigh from 3 to 4 cwt.; and cost from £5 to £6.

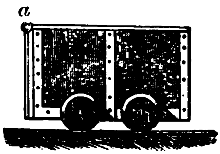

Fig. 48.—Tram-Waggon, flanged wheels. Door at end, hinged at *a*, made of iron plates, riveted.

Sometimes the waggons are made with plain wheels to run between tram-plates, of the form shown in fig. 49, at *a*, but a saving of iron is effected by using flanged wheels

running upon wooden rails, 3 inches high and 2 inches wide, faced with thin bar iron, or upon iron rails nailed to wooden sleepers. Three forms of rail are shown in fig. 49, at *b c d.* A convenient width between the rails is 36 inches, but the writer has seen guages in use in Cornwall and South Wales varying from 42 inches downwards to 14 inches, the latter being used for the narrow levels in an old iron mine. The rails used weigh from 10 lbs. to 20 lbs. per yard of length.

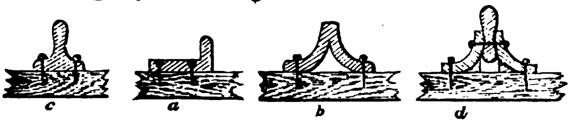

Fig. 49.

98. The tram-waggons are pushed along by boys or men, sometimes pulled by donkeys or horses, and in a few instances hauled along by wire-ropes or chains, which are coiled around winding-drums worked by stationary engines. Where possible the rails should have a downward inclination of about half an inch per fathom in the direction of the load, as this greatly facilitates the movement of the heavy weight, without materially impeding the return of the empty waggons. In the iron mines of the North of England and South Wales much greater inclinations are rendered neccessary by the situation of the ores, and "tail-rope haulage" is exceedingly common.

99. Methods of Raising Ore.—The stuff having reached the shaft has next to be raised to the surface. From depths not exceeding 15 or 20 fathoms, the "tackle" or windlass shown in fig. 53 may be used with advantage. This plan is not to be recommended for greater depths, as the cost may be considerably lessened by the use of other appliances—the "horse-whim," derrick or whipsey-derry, water balance, or steam engine—described in the chapters on machinery for raising ore and pumping.

The ore is raised either in "kibbles," "skips," or "cages."

The kibble is simply an iron bucket made of boiler plates, riveted together as shown in figs. 41 and 53. They are attached to chains, hempen or wire ropes, and vary in capacity from 1 to 25 cwt.

The small kibbles used with the tackle are called "winze-kibbles." They are made about 14 inches high and 12 inches in diameter; holding from 1 cwt. to $1\frac{1}{4}$ cwt.

Whim-kibbles are of nearly the same form as winze-kibbles, but they are from 20 to 24 inches high, 14 to 18 inches wide, and made of somewhat thicker plate, with a loop below for greater facility of upsetting in landing. They hold from 4 to 6 cwt.

Kibbles of very large dimensions are occasionally used for deep shafts, and worked by water wheels or steam engines. At Dolcoath mine, in Cornwall, very large kibbles, capable of containing a ton or more of tin stuff, are worked in some of the old irregular shafts. The largest of these are more than 4 feet high, and about 3 feet 6 inches wide.

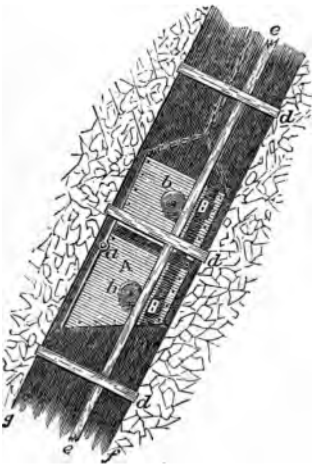

Fig. 50.—A, THE SKIP, with a hinged door at *a*, wheels at *b*, and guide pieces at *c*, *c*; *d*, *d*, cross timbers let into sides of shaft; *e*, *e*, guides; *f*, foot-wall; *g*, hanging wall of lode.

When kibbles are used in deep shafts it is because they are much inclined and somewhat irregular. The lower side or foot-wall is often partially or entirely lined with "bed-plank" to reduce the friction. The amount of wear, however, of bed-plank and kibble is very great, the friction is enormous, and the breakages, owing to the

excessive strain on the ropes and machinery, are very frequent; so that the use of kibbles for deep or permanent shafts is not to be recommended. A much better plan is to straighten the shaft as much as possible, to put in guides or shaft railways, and to use skips running upon wheels as shown in fig. 50. These skips are now commonly raised by means of wire-rope, but unless the railway be put in very carefully the friction is still considerable, and in Cornwall a speed of 360 feet per minute has rarely been exceeded. For highly inclined shafts, the skips should have wheels as shown in the figure; but when the shaft is nearly vertical, simple guides will suffice. Fig. 51 is a plan of a shaft with double skip-road adapted for wheels, and fig. 52 a similar shaft arranged with "cover and filler" roads for guided skips. The cost of putting in a double skip-road or shaft railway will vary from £1 10s. to £3 10s. per fathom of length.

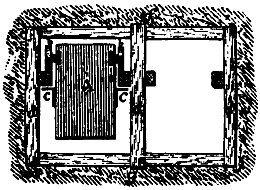

Fig. 51.—Plan of Double Skip-road or Shaft Railway. A, the skip; *b*, the wheels; *c*, *c*, guides; *d*, *d*, shaft timbers; *e*, *e*, the rails.

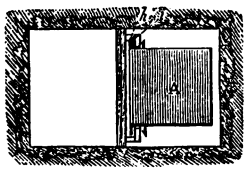

Fig. 52. — Plan of Double "Cover and Filler" Skip Road. A, the skip; *i*, the "cover;" *h*, the "filler."

The skip shown in fig. 50 is filled sometimes at the upper end, but sometimes the rails are bent round so as to allow it to take a horizontal position at the bottom of the shaft, when it is filled by opening the hinged door. This door is then secured with a catch until it reaches the surface, where the "lander" brings it over his waggon and opens the door, so allowing the stuff to slide down the sloping bottom.

Wherever possible, the use of a pair of cages running in a vertical shaft is to be recommended. These are arranged so that the loaded waggon from the "end," "stope," or "face of work" may be run directly into the cage, and raised to the surface with only one loading. In this manner a much greater speed may be attained; and nearly twice the quantity may be raised from the shaft with the same power as in the case of a pair of skips.

100. Comparative Cost.—From shafts from 10 to 15 fathoms deep, two men will raise on an average, with the tackle, about 12 tons in eight hours. The cost of this in Cornwall is 6s., or say 6d. per ton, or ½d. per "ton-fathom." For depths of more than 15 fathoms a less quantity will be raised, or else a third man will be required, and the cost will be about ¾d. per ton-fathom. A hempen rope about 1¼″ diameter, called a tackle-rope, is generally used with the tackle.

With a one-horse whim, one man to receive the stuff and a boy to drive the horse, from 15 to 20 tons per eight hours may be raised from a depth of 40 fathoms. The cost will be in Cornwall about 9s., or, say, 6d. per ton as before, but the depth being greater it will only be about 1-6th of a penny per ton-fathom. To raise a greater quantity, or from a greater depth, two horses will be necessary.

With the "derrick" or "whipsey-derry" the cost will be a little more than with the horse-whim. Whim kibbles are often raised by means of chains, but the use of chains in shafts is not to be recommended.

With large kibbles working in shafts of from 150 to 300 fathoms deep, from 20 to 30 tons per day of eight hours may be raised—the larger quantity, of course, from the shallower shaft. When engine power is used, the cost will be about 10s. to 12s., or, say, 1-30th of a penny per ton-fathom on an average. A water-wheel will save about 2-5ths of this.

With a well-arranged skip and shaft railway the cost of raising ore, even where a steam engine is used,

will be reduced to about 1-50th of a penny per ton-fathom, or less; and with a pair of cages in a vertical shaft with good arrangements will not exceed 1-100th of a penny per ton-fathom.

101. In metal mines, where ores of a considerable specific gravity have to be dealt with, large cages are seldom needed. A waggon 30″ × 42″ × 20″ will hold about one ton of iron ore, and this is as much as it will be generally necessary or desirable to raise at one time. With good arrangements, a shaft of 12 feet by 9 feet will be found large enough to allow of ample pumping space, a good ladder-way, and a pair of cages capable of raising 20 tons per hour from a depth of 200 fathoms.

From the foregoing remarks it is evident that kibbles are only suitable for shafts of moderate depth, and preferably for those which are nearly vertical. Cages are only suitable for vertical shafts, but are valuable for all depths. For inclined shafts, skips running upon wheels are most suitable; and it will be worth while in every case to pay great attention to the rails or guides upon which they run. Where the inclination of the shaft from the horizontal does not exceed 1 in 3, as in many ore beds and some few "flat" lodes, the ore may be brought up in the tram-waggons from the levels without using skips or cages, the same tramway being continued up the incline to the surface. In all cases, if at all possible, double roads should be used, or two pits should be put into communication to cause the weight of the descending cage to balance that which is ascending, so that the mineral only shall be lifted. Sometimes where both these modes are for some reason unsuitable, a "dummy" counterpoise may be used.

102. Ropes.—For shallow pits chain or hemp rope may be used with great propriety, because of the facility with which it may be coiled round small barrels or drums; but for considerable depths, and especially where great weights have to be lifted, the use of wire rope in some

form is both safer and much more economical—and is, indeed, now almost universally used. Wire-ropes may be either round or flat, of iron-wire or steel. For round iron-wire ropes, drums of less than 12 feet should never be used; for flat ropes and ropes of steel wire, drums somewhat smaller may be used, but are not to be recommended in general.

103. The following tables of the equivalent working strengths of chain, hemp rope, iron-wire rope, and steel-wire rope, will be useful to the young student. They all refer to material of best quality.*

TABLE 1.—WEIGHT AND STRENGTH OF CHAINS.

Diameter of iron,	5/16 in.,	11/16 in.,	15/16 in.
Weight per Fathom,	5½ lbs.,	28 lbs.	49 lbs.
Working Load,	24 cwt.,	54 cwt.,	120 cwt.

TABLE 2.—WEIGHT AND STRENGTH OF GOOD HEMP ROPE.

Circumference,	5½ in.,	8 in.,	12 in.
Weight per Fathom,	7 lbs.,	16 lbs.,	36 lbs.
Working Load while new,	24 cwt.,	54 cwt.,	120 cwt.
Breaking Strain,	8 tons,	18 tons,	40 tons

TABLE 3.—WEIGHT AND STRENGTH OF IRON-WIRE ROPE.

Circumference,	2⅛ in.,	3⅜ in.,	4⅝ in.
Weight per Fathom,	4 lbs.,	9 lbs.,	20 lbs.
Working Load,	24 cwt.,	54 cwt.,	120 cwt.
Breaking Strain,	8 tons,	18 tons,	40 tons.

TABLE 4.—WEIGHT AND STRENGTH OF STEEL-WIRE ROPE.

Circumference,	1¾ in.,	2½ in.,	3¾ in.
Weight per Fathom,	2½ lbs.,	5½ lbs.,	12 lbs.
Working Load,	24 cwt.,	54 cwt.,	120 cwt.
Breaking Strain,	8 tons,	18 tons,	40 tons.

104. As shewn in the tables, a very large allowance of strength is made for safe working, the working load being

* Very complete tables of equivalent strengths are given in Molesworth's "Pocket-book of Engineering Formulæ."

taken at less than one-sixth of the ultimate strength. With hemp rope and chains a greater allowance should be made, on account of the imperfection of material and workmanship to which they are specially liable. A large allowance must be made, too, for the strain due to the extra pull in starting. Sometimes this is somewhat relieved by mounting the bearings of the winding pulley or drum upon springs, but even when this is done the extra strain will be very considerable.

The weight of the chain or rope itself must be taken into account when any considerable length is used, and this too will be much greater with chain or hemp rope than with wire rope. Indeed, for deep pits the use of chain would be forbidden by this consideration alone, as a chain of 300 fathoms long, capable of working with a load of 24 cwt., would itself weigh nearly one ton, while a steel-wire rope of the same strength would weigh only 750 lbs.

To relieve the winding engine, and to enable it to overcome the weight of a long length of rope, the size of the drum is made to vary, or the speed of winding at first is reduced. This may be effected either by using a conical winding drum, or by using a flat rope and causing it to wind upon itself.

CHAPTER XIV.

MACHINERY FOR RAISING STUFF.

105. The Tackle.—The first machine used in mining operations for raising ore or deads is usually the tackle or windlass, shown in fig. 53. This is so simple that it scarcely needs a detailed explanation, but as it is usually made on the spot by the mine carpenter, a few words may not be out of place.

The carpenter selects two pieces of "half-timber" *a a* long enough to reach across the shaft, and strong enough

to bear the weight. These are called the "bearers," and they are afterwards planked over, except the small space required for the kibbles. In the middle of these half-timber bearers the uprights *b b*, made of planks from 10 to 12 inches wide, 4 feet 6 inches long, and $1\frac{1}{4}$ to $1\frac{1}{2}$ inches thick, are morticed. In the upper end of each upright a slot, about 10 inches long and $1\frac{1}{2}$ inches wide, is cut, and the bottom lined with iron, to receive the iron handles, and to prevent the wood from splitting. The barrel *c* is made of a piece of Norway pine, from 4 to 6 feet long, and 8 or 10 inches thick. The ends of the barrel are strengthened with iron bands to prevent them from splitting when the handles are driven in.

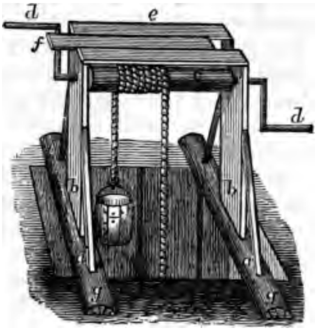

Fig. 53.

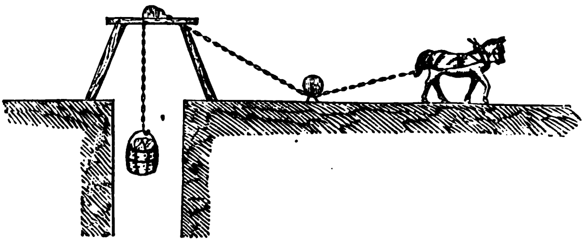
Fig. 54.

The handles *d d* are made of 1″ or $1\frac{1}{2}$″ round iron, bent as shown, and squared and tapered at the ends for driving into the barrel. The handles serve also as an axle for the winding barrel.

A piece of wood *e* is then fastened across the top of the

tackle, and a groove is made in it to receive a sliding piece *f*, which, being pushed out beyond the bend of the handle, holds it when required, keeping the load from descending. Sometimes stays are fixed extending sideways from the uprights, as shown at *g g*. The cost of preparing and fixing this shaft-tackle should not exceed 25s. or 30s. for timber, iron-work, and labour. The tackle is well adapted for raising material from depths of less than 15 fathoms; for greater depths, up to 50 fathoms, the derrick or "whipsey-derry," fig. 54, is sometimes used, but it is slow in operation, and has little to recommend it except its small first cost, which is from £2, 10s. to £3, 10s.

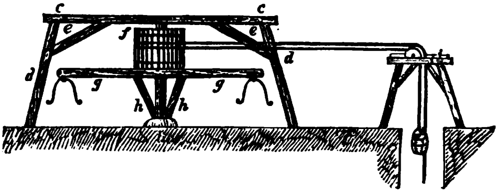

Fig. 55.

106. The Horse-Whim, shown in fig. 55, is a much more efficient machine. This, too, is made on the mine, the mode of construction being as follows:—The axle *a* is of oak, about 12″ diameter, and 12 or 14 feet long. Three sets of arms are morticed into this at distances of 6, 8, and 10 feet from the lower end. Upon these arms wooden segments are nailed, and upon these again the 4-inch planks which form the barrel or cage. Each end of the axle is bound with iron, and each has an iron centre attached. The lower one works in a block of stone, shown at *b*, the upper in an iron socket fixed to the span beam *c c*. This is made of a piece of Norway or Swedish fir, 36 feet long and about 10 inches square, supported by the legs *d d*, which are morticed into the beam, and frequently strengthened with iron strapping plates. Stays are added at *e e*. The barrel *f* is 10 feet diameter; be-

neath it is placed the driving beam *gg*, 30 feet long, and strengthened by the stays *h h*. At one or both ends of the driving beam a bar of iron is fixed with a yoke to which a horse may be attached. The total cost of such a whim as here described is under £20, and it is a very efficient machine indeed.

107. The Poppet Heads are shown over the shaft to the right of the whim. The construction is as follows:— Two timber "horses" *i i* are first formed. The legs are 12 feet long, and as thick as possible, but not less than 10 or 12 inches. These are partly sunk in the ground, and the upper ends are morticed into the "caps," which are 9 or 10 feet long. The horses are placed one on each side of the shaft, about 5 or 6 feet apart, the centre of the space between being in line with the span-beam of the whim.

Carriers are placed across the horses, and the bearings of the pulleys rest upon these. The pulleys are usually of different sizes. Where chain or hemp ropes are used for hauling, one may be about 4 feet and the other 2 feet, each being 4 inches wide. Wire rope is seldom used with a whim, but should it be used, the pulleys must be much larger. The total cost of the poppet heads for whim drawing will not much exceed £6. Very similar poppet heads, but larger, are used in many cases when winding with a steam engine or water wheel.

108. It is not often that water wheels are arranged for hauling purposes, although in some instances, as at Wheal Friendship, near Tavistock, they have been used with excellent effect. The only peculiarity is the application of suitable gear for reversing or stopping the motion. There is no great difficulty in this, but the inconvenience is sufficient to prevent their extended use for such a purpose in shallow mines, and in deep mines a sufficiency of water power is rarely available, and what there is may be often more advantageously used for pumping. We shall therefore reserve our remarks upon water wheels for the chapter on "Pumping Machinery."

An easy and convenient but not economical mode of using a fall of water for winding purposes is shown in section in fig. 56. The water enters at *a*, and falls upon the leaves or buckets of the wheel *b*, making its escape at *c*.

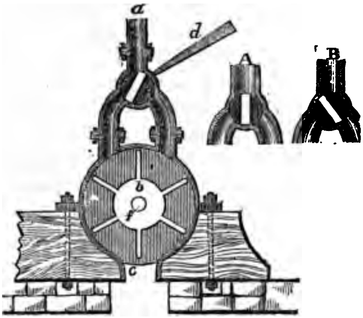

Fig. 56.

A cogwheel is mounted upon the axis *f* outside the working barrel, which serves to communicate motion to the winding drum *g*, shown in fig. 57. The motion is stopped or

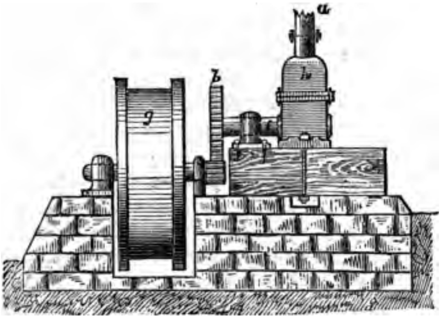

Fig. 57.

reversed by the handle *d*, which moves the valve *e*, bringing the channel successively into the positions shown at A and B. The whole arrangement is as shown in fig. 57,

where *a* is the inlet for the water, *h* is the case containing the working wheel, *i* is the cogwheel fixed on its axis, and *g* the winding drum. This mode of using water power is suggested by a working model which is now in the Museum of Practical Geology in Jermyn Street, London. It is cheap, compact, and easily constructed, and but little likely to get out of repair, but the author is not aware that it is anywhere in use. When the fall of water is great this simple arrangement will be found very efficient.

109. The Water-Balance.—In many of the open works on the northern side of the great coal basin of South Wales, water-balance machines are largely used for winding purposes, and for mines of not more than 100 fathoms deep; in a district affording a good supply of water, and free drainage by means of adits, they may be highly recommended. Sometimes they are used when there is no drainage, the water being pumped up from the bottom by an engine, but this is not to be recommended. In some cases the machines are placed at different levels, so that the same water is used five or six times over as many successive lifts. The tram, containing from 12 to 20 cwt., is placed in a cage over an empty water bucket, and the empty tram on a similar bucket at the top. Water is then made to flow into the upper bucket until its weight is great enough to cause it to descend, so raising the filled tram. On the arrival of the full bucket at the bottom of its fall a self-acting valve opens and the water is discharged, so allowing the process to be repeated. The buckets are made of ½″ boiler-plate, circular in form, and some hold more than 2 tons of water. The landing chain is balanced by a chain which hangs below each bucket, and guide chains are used to keep the buckets from striking each other when the shafts are not divided. A speed of 300 to 400 feet per minute is easily attained by this machine, and the total cost of raising stuff is about 1½d. per ton per 50 fathoms. For great depths the weight of the machinery becomes so great that the economy is reduced or disappears. Somewhat similar machines are

used in some of the iron mines of North Lancashire and Cumberland.

110. The Steam Engine.—For hauling in deep mines a steam engine is generally necessary, and although many forms of steam engine are employed for this purpose, our remarks will apply to two only—the double-acting high-pressure condensing engine, and the double-cylindered horizontal engine. Both these machines work the steam expansively, and both give good duty when in good order and when well attended; but the preference in the future will probably be given to the horizontal engine, everywhere, at any rate, except in Cornwall.

The Cornish winding engine differs but little from the Cornish pumping engine, hereafter to be described, except that it is double acting, *i.e.*, it takes its steam on both sides of the piston instead of only on the upper side. It is, however, supplied with a heavy fly wheel to equalise the motion as much as possible. The driving crank is placed between the fly wheel and the winding drum. Neither a very rapid nor an equal motion is obtained by this form of engine, and the double-cylindered horizontal engine is on the whole much to be preferred. The Cornish double-acting engine is sometimes used for pumping, or for driving stamping or crushing machinery.

111. Horizontal Engine.—The cylinder of this engine is fixed in a horizontal position, as shown at AB in fig. 58. High-pressure steam is admitted alternately on each side of the piston. The piston-rod is terminated by the crosshead *g*, which works backwards and forwards between the guides *a b*. To this crosshead the connecting rod *g c* is attached, and this turns the drum or fly-wheel by means of the crank C and the main shaft *r*. The whole is fixed on heavy masonry as at C D. To equalise the motion two cylinders are used with their cranks at right angles, so that one is exerting its greatest amount of force while the other is at its dead point. A common form of governor is shown at G. To economise steam it is used expansively. The condenser and its

connections are not shown in the sketch, but they may be placed in any convenient situation. For winding purposes they are fitted with reversing gear and powerful friction brakes.

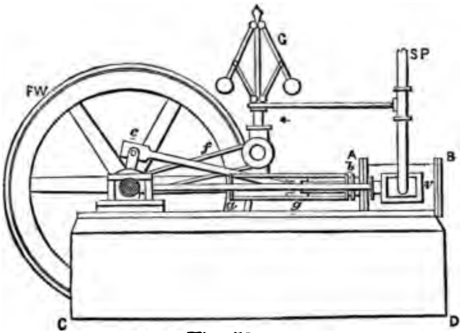

Fig. 58.

The advantage of the horizontal over the beam winding engine is greater compactness and less first cost for equal power, a saving of cost in the necessary buildings, and, if two cylinders be used, a more equable motion. Its only disadvantage is that the cylinders are apt to lose their true form, the lower part becoming more worn than the upper, owing to the weight of the piston. A remedy for this has been found by mounting the piston on the centre of a long piston-rod which passes through stuffing boxes placed at each end of the cylinder.

Every winding engine should be fitted with some form of indicator, showing the attendant the exact position of the skip or cage in the shaft at a glance, as in this way many accidents from over-winding may be prevented. To prevent loss of steam by condensation in the steam-pipe, cylinders, etc., these parts, as well at the top of the boilers themselves, are covered with some non-conducting material. The modes of doing this will be explained in a future chapter. The principal forms of boilers will also be there described and illustrated.

CHAPTER XV.

THE DRAINAGE OF MINES.

112. THERE are few situations where workings can be carried to any considerable depth below the surface of the ground without interruption from the accumulation of water. The surrounding rocks always contain more or less of water, which occupies their joints, fissures, or cavities, and this water rapidly accumulates wherever the excavations are deepest, and must be removed in order that the works may be carried on.

113. **Adit Levels** are driven in many cases to draw off this water as fast as it gathers, wherever the formation of the ground is favourable. Such adit levels are shown in fig. 2, p. 25, and fig. 11, p. 35. In some instances very extensive districts have been drained by adits to depths of many fathoms. Thus the great Gwennap adit in Cornwall, which was constructed about a century ago, drains nearly 30 square miles of country by means of branches to a depth varying from 30 to 90 fathoms. The total length of this adit, with its branches, is about 40 miles. Another great adit, known as the Ernst August adit, was finished a few years ago in Saxony, and drains a large series of mines in the Hartz Mountains, some of them to a depth of 214 fathoms. This adit, with its branches, is 14 miles in length; part of it is navigable by boats; and it occupied nearly 13 years in construction—costing £85,500.

Sometimes, however, an adit is inadmissible or insufficient, thus—if the mine is situated in a very low place, if it occupies an isolated portion of country, if the water be required at the surface for ore-dressing operations, or if the ground be so little uneven that a very long level would be required in order to drain any considerable depth of workings, some different mode of drainage is necessary.

114. Pumps and Pitwork.—In trial shafts for workings of small extent, or in a country already partially drained by surrounding mines, water buckets may be used, the water being raised by means of the tackle shown in fig. 53, or the horse-whim, fig. 55. As the water increases, however, this mode is found quite inadequate, and some form of pump is necessary.

The common suction pump, shown in fig. 59, is rarely used in mining operations, as it will only raise water to a height of about 30 feet, but occasionally, and for temporary purposes, such pumps are used in successive lifts. The mode of action is as follows:—

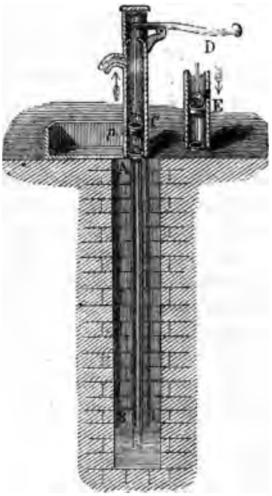

Fig. 59.

The long pipe A B is called the suction pipe, and it must be long enough to reach into the water in the well. The upper end of the suction pipe is furnished with a valve E opening upwards. Above the suction pipe is the working barrel C, containing a well-fitting piston *p*, which is worked up and down by the lever or brake-staff D. This piston or "bucket" contains a valve *v′* opening upwards. When the working begins the water in the suction pipe A B stands at the same level as that in the well. On raising the piston as indicated by the arrow, the valve *v* rises, and the air between it and the water in the suction pipe is rarefied, and the pressure of air on the water in the well causes it to rise in the pipe. When the piston is depressed as at E the valve *v* at the top of the suction pipe closes, that in the piston *v′* opens, and the excess of air

between v and v' passes out into the general atmosphere. The piston is now again drawn up, the water rises again in the suction pipe, and at length—if the suction pipe is not more than 30 feet long—passes through the valve v into the working barrel. The piston now again descends, and the water passes through its valve v', and when it is again drawn up this valve closes, the piston serves as a bucket to raise the water as far as the spout, from which it flows in an intermittent stream. The water thus rises because the pressure of the air upon its surface in the well is greater than the pressure in the suction pipe. If all the air in the pipe were to be withdrawn it would rise until the weight or pressure of water AB was the same as that of the air on the water in the well, or about 15 lbs. to the square inch, varying a little from time to time. This pressure is given by a column of water about 34 feet high. Owing to the difficulty of making all the fittings air-tight, about 30 feet is all that can be ordinarily reckoned upon.

Practically, it is found that if the distance AB is 30 feet or under, water may be raised by means of this pump, but if more than 30 feet, the pump will fail. For greater depths, therefore, the pump is modified slightly, as shown in fig. 60. The suction pipe *a*, now called the "windbore" or "snore," is reduced to about 10 or 12 feet, and pieces of pipe, called "pumps," are added above the working barrel to the required or most convenient height —often more than 100 ft. The whole arrangement is now as shown in fig. 60, and is called a "bucket" or "drawing" lift: *a* is the windbore, *b* is the "door-piece" containing the valve or "clack" *c*; *o* is the door, *d* is the bucket with its clack, *e* is the working barrel, which is bored truly cylindrical, *f* is the first of the "pumps," all of which are about 1 inch greater in diameter than the working barrel. The different pieces are made with flanged joints as shown, for convenience of fixing; *g* is the "collar-launder," from which the stream of water is delivered.

This kind of drawing lift is well suited for use in a shaft which is being continually deepened, as additional pumps may be added at the top from time to time. If, however, the depth is more than about 30 fathoms, the water is usually raised in two or more distinct lifts—the drawing lift delivering its water from the collar-launder *r*, fig. 61, into a cistern A, from which it is forced to the surface by the "plunger" or ram *a*, shown in the figure. By the ascent of the plunger "pole" *a* in the "case" *b*, the water which fills the cistern A is made to rise through the wind-bore *h* and clack *c* into the H piece H. When the pole descends, the clack *c* closes, the water raises the clack *e*, and passes upwards into the pumps above. As the pole again rises, the clack *e* is closed, *c* opens, and a fresh portion of water passes into the H piece. The cistern is kept full by the delivery of water from the top of the drawing lift by the collar-launder *r*, and also, in many cases, by the water from the upper portion of the mine, which is led into it instead of being allowed to fall to the bottom of the mine; *f* is the top pump of the drawing lift, and *f′* the bottom pump of the plunger lift. The plunger pole *a* works in the case *b* through a stuffing box at *i*. The mode of attaching the plunger pole *a′* and the bucket-rod *k* to the main rod *l l*, by means of the "glands" *m m*, and the "set-offs" *n n*, is clear from the figure.

115. The pumps are made of cast iron, generally in lengths of 9 feet, but with a few shorter "matching pieces" in 3 and 6 feet lengths. They are cast about $\frac{3}{8}$ths to $\frac{5}{8}$ths of an inch thick, according to size, intended height of lift, etc., with several projecting ribs for strength. The flanges are about 1 in. thick. The valves or "clacks" are usually of leather strengthened with iron, and it is here that the wear is greatest. The chief peculiarity is, that the hinges or centres of the valves work within guides instead of upon centres, so that the whole valve has liberty to rise a few inches, thus giving a greater water space in the early part of the stroke.

Sometimes valves of metal, variously constructed, are

used, and occasionally the valves are partly or entirely made of india-rubber.

For convenience of access to the valves they are placed in "door-pieces," as shown in side view in fig. 60, where *o* is a movable door giving access to the valve *c*.

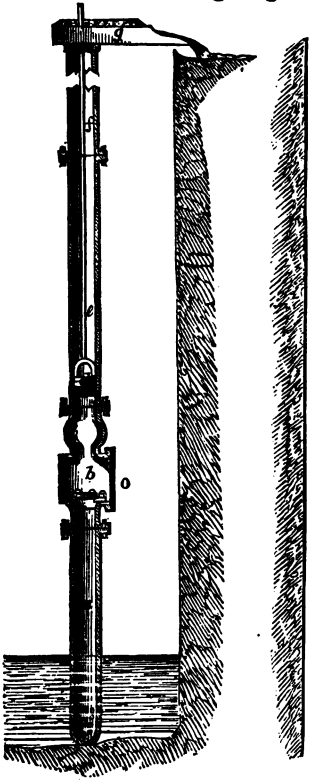

Fig. 60.

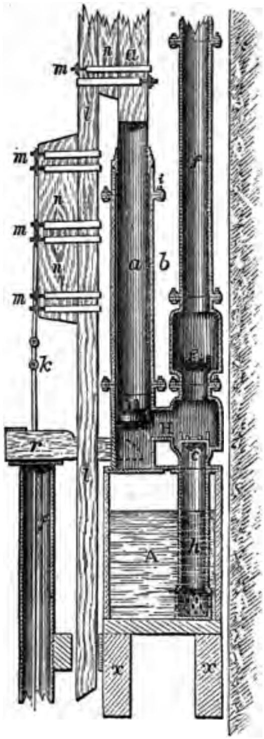

Fig. 61.

116. The cisterns for the successive lifts are made of

wood 3 inches or more in thickness, strongly bound with iron strapping plates, and supported on strong "bearers," *xx*, fig. 60, which are let into the sides of the shaft.

117. Sometimes the water to be raised is of a highly corrosive nature, especially that from copper and lead mines. In such cases it is good economy to make the valve seats, working barrel, and other important parts, of gun-metal, and to line the pumps with thin staves of oak or other hard wood.

118. The "pumps" are fastened together with bolts and nuts, "flange-pins," as they are called in Cornwall, where it is customary to place between the flanges rings of thin iron bound round with "bal-shag," a coarse kind of flannel. This, when tightly screwed up, makes the joint air-tight, while it does not interfere with the ready separation of the pumps in case of need.

119. The "main rod," part of which is shown at *l l*, fig. 61, is in deep mines made of the longest and straightest balks of Norway pine which can be obtained. The secondary rods are attached to this by "set-offs," as shown at *nn* in the same figure. The different lengths of the main rod are halved together, bolted through, and secured with strong strapping plates.

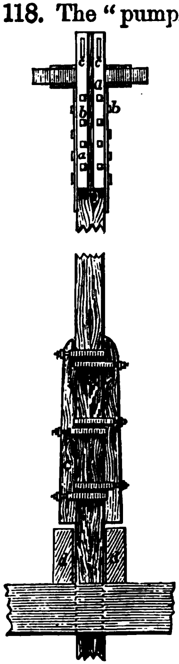

Fig. 62.

The upper end is attached to the outer end of the engine "beam" or "bob" by wrought-iron straps, secured by bolts *b* and cottars *c*, as shown in fig. 62.

At intervals down the shaft catch-pieces *c c* are secured, *and bearers fixed* across *d d*, in order to take up the

weight of the rods in case of a breakage, to prevent the whole mass of many tons weight from falling to the bottom of the shaft. They also prevent the engine from making too long a stroke, or going too far out, and so breaking off the cylinder cover.

The water is raised in the lower or drawing lift by the up or "in-door" stroke of the engine, but the remaining, or plunger lifts, are worked by the down or out-door stroke; the weight of the rods forcing the water up the column of pumps.

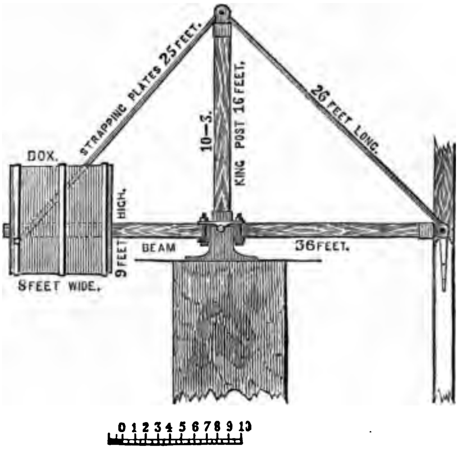

Fig. 63.

120. Balance Bobs.—When the mine is deep the weight of the rods is more than sufficient for this purpose, and the surplus is generally counterbalanced by "balance-bobs," placed either at surface or in chambers excavated by the side of the shaft underground. Thus, at Davey's engine at the consolidated copper mines in Gwennap, Cornwall, the main rod was one-third of a mile long, and weighed 95 tons. The other rods weighed 40 tons, or *together 135 tons.* 39 tons were required to balance the

column of water in the pumps, and the remaining 96 tons were balanced—partly by counter-weights, partly by special hydraulic machinery. One of these balance-bobs is shown at fig. 63.

For raising the heavy portions of "pit-work," as this pumping machinery is called, a powerful "capstan" is fixed just outside the engine-house.

Very few of the shafts in the Cornish mines are vertical, and many are of varying inclination, so that it is necessary not only to provide friction rollers, but also to connect the different sections of the main rods by angle-bobs. One mode of doing this is shown in fig. 64, where a portion of the ground at the side of the shaft is cut away for the reception of the "balance-bob" *v*, the arms of which are pivoted to sections of the rod *aaa*. Other modes of effecting change of motion by friction wheels and guide rails are used where, from the hardness of the ground or other reasons, this mode is inadmissible.

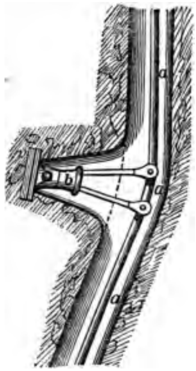

Fig. 64.

CHAPTER XVI.

OF MACHINERY FOR WORKING PUMPS.

121. Many different forms of machinery are used for giving motion to the pumps which drain mines, but the more important and permanent forms are generally comprised under the two heads of "Water Wheels" and "Steam Engines." The water wheels used are mostly of the kind termed "overshot," and the most efficient of the steam engines used are those known as Cornish pumping engines,

122. Water Wheels.—For falls of water from 20 up to 50 feet, the large proportion of useful effect, and the simple construction of the overshot water wheel, will probably account for its almost universal adoption. To apply an overshot water wheel for pumping purposes, little more is necessary than the attachment of a crank and connecting rod to one end of its axle. The other end of the connecting rod, which may be short or long, in one or many pieces, is attached to the king post of a balance bob, and a reciprocal motion is at once obtained through the revolution of the crank. Sometimes the power is transmitted from the wheel to the pump rods by means of a wire rope or chain, and the weight of the descending pump rods takes up the slack of the rope and keeps it tight on the return journey. Fig. 65 shows this arrangement, but it is rarely adopted where the wheel is so close to the pumping shaft as is there shown.

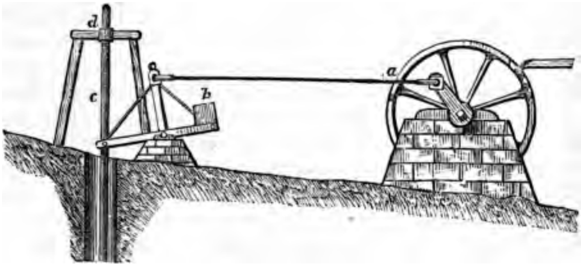

Fig. 65.

In order to get the largest proportion of work out of a given fall, the wheel is frequently made several feet higher than the total fall. The water is then brought upon the shoulder of the wheel as shown in fig. 66; the launder *a* having a little fall given to it, so that the water may reach the wheel with a little more velocity than that of the circumference of the wheel itself. The wheel works more smoothly when dealt with in this

manner than in any other. The water should reach the wheel at the point *b*, which is between 30° and 40° from the top of the wheel *c*. The wheel shown in the fig. is of iron, having 10 wrought-iron arms *d d* rivetted or bolted to the centre, and to the shrouding. The shrouding *e e e*

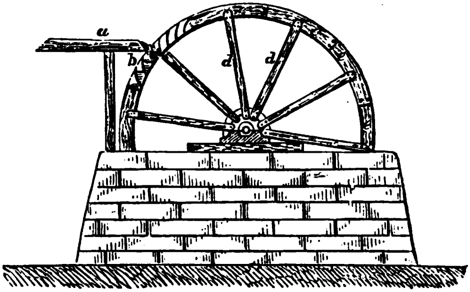

Fig. 66.

is in segments, which overlap and are bolted together between the arms. The buckets are covered by this shrouding, but a small portion is removed in order to show them at *b*. The axle of the wheel works upon brasses fitted into plummer blocks, which are mounted upon piers or "loadings" of masonry. In all water wheels the water should be brought on to the wheels in a thin sheet of somewhat less width than the breast of the wheel itself; the buckets should be large enough to receive all the water without any overflow at the sides, and so curved as to hold it all until nearly at the lowest point, and then to discharge it all at once before that part of the wheel begins to rise. Falls of water may also be utilised by means of "breast wheels," "Poncelot wheels," "undershot wheels," "turbines," and "water-pressure engines," but the space at our disposal will not allow of their description here.

123. Pumping Engines.—It is evident that any form of steam engine may be so arranged as to give an alternate motion to the pump rods in the shaft; but for

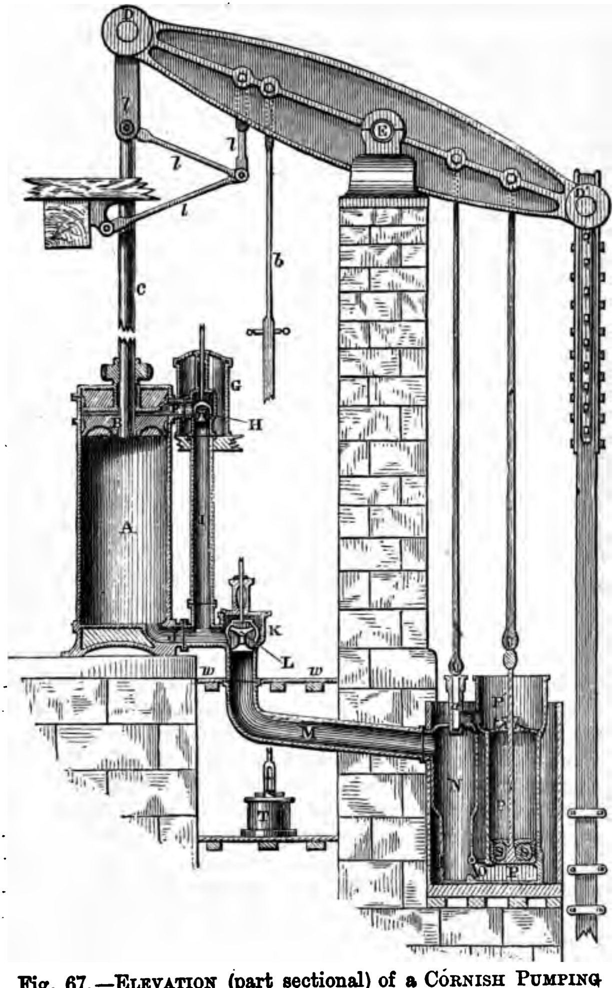

Fig. 67.—ELEVATION (part sectional) of a CORNISH PUMPING ENGINE.

permanent works, where large quantities of water have to be continuously raised, the Cornish pumping engine, in combination with the Cornish tubular boiler and arrangement of flues, has proved itself superior to all its competitors. The Cornish pumping engine may be described as a single-acting, high-pressure condensing engine. These engines are of course constructed at an engineers' establishment away from the mine. They are very simple and strong in construction, and require but little repair. When once fairly at work, many of them work continuously for years, with only occasional stoppages for packing the piston or other minor repairs, so that it is not necessary for the young miner to have more than a general idea of their construction and mode of working. This is given in fig. 67. A is the cylinder, B the piston, C the piston-rod, which is attached by the links *l l l* of the "parallel motion" to the inner or "in-door" end D of the great beam or "bob" D D′. To the outer end D′ the upper end of the main pump rod is attached. The beam is usually made unequal, *i.e.*, the inner portion from the gudgeon E to the end D is longer than from the same gudgeon to the outer end D′. The length of stroke in the pumps is thus less than that in the cylinder, and the velocity of the water less in the same proportion than that of the piston. This is done to lessen the shock of the water in the pumps on the sudden closing of the valves when the stroke is reversed. Engines with 10′ stroke in the cylinder have often 6′, 8′, or 9′ only of stroke in the pumps. F is the steam port communicating with the top nozzle G. This top nozzle contains three valves, of which only the centre one, called the equilibrium valve, is shown in the drawing at H. This communicates through the equilibrium pipe I with the lower port J, and so with the space in the cylinder A under the piston B. K is the bottom nozzle containing L, the exhaust valve which covers the entrance to the eduction pipe M. This communicates with the condenser N, and this again by the foot valve

O with the air pump P. The condenser and air pump stand side by side in a cistern of cold water. The mode of starting and working may be briefly described as follows.

124. Starting the Engine.—When it is intended to start, and the steam is at the required pressure in the boiler, all the valves are opened by the engineer, when the steam speedily fills the cylinder and all the valves and passages, and, rushing through, forces out the air. This is called blowing through. The cylinder retains the air longest, and to get rid of it after the steam has blown through for a few minutes, the "steam" valve, which is placed on the left hand side of the equilibrium valve H, shown in fig. 67, is closed for a little. The steam in the eduction pipe is soon condensed by the cold water around the condenser, and the air rushes from the cylinder to supply its place. The steam valve is again opened to blow this air out of the eduction pipe, and this alternate opening and shutting of the steam valve may need to be repeated several times until all the air is out of the cylinder. The engineer now examines his vacuum guage to see whether he has any vacuum in the condenser. He may probably have a vacuum equal to two or three inches of mercury when he opens the "injection" cock (not shown in the drawing) a very little, and allows a little cold water to pass into the condenser. If this produces a considerable vacuum, he opens the exhaust valve L and the injection cock at the same time, when the engine will probably commence to move indoors, the piston *descending* in the cylinder. If the engine does not move, the blowing through must be repeated. If the engine be lightly loaded, or if there be but little water in the pumps, the regulator valve from the steam pipe (not shown in the drawing) must only be opened a very little so as to supply very little steam, or else the engine is liable to make its in-door stroke with much violence, and perhaps do mischief. To guard against such accidents, "catch-pieces" similar to those shown at *c*, fig. 62, but reversed, are often fixed on the main-rod in the shaft, and other

"in-door catch-pieces" are fixed to the inner end of the main beam.

125. Working the Engine.—The top nozzle G contains three valves, only one of which is shown in fig. 67. The valve farthest from the spectator is called the regulator valve. This guards the entrance of the steam pipe from the boiler, it is only occasionally altered by the engineer, being opened by means of a screw, and kept open, more or less, all the time the engine is working. By opening the regulator valve, the top nozzle is kept full of steam.

Another valve, not shown in the figure, is the steam valve; this is situated on that side of the top nozzle nearest the spectator. The steam valve is opened at the commencement of each stroke of the engine, when the steam passes in through the steam port F, and presses on the top of the piston and forces it down, so making the in-door stroke. In Cornish engines the steam is used expansively, *i.e.*, it is admitted to the upper part of the cylinder at a high pressure, and cut off by closing the valve when a small proportion only of the stroke is made. The steam already in the cylinder expands until it fills it; so forcing the piston to the bottom of the cylinder, and completing the in-door stroke.

The equilibrium valve H is then opened and the exhaust valve L closed, the steam rushes down the pipe I, and through the lower port J, and so presses upon the lower side of the piston as strongly as upon its upper side, thus producing equilibrium. The weight of the pump rods then being no longer overcome by the steam pressure on the upper side of the piston, pulls down the outer end D′ of the beam, and the engine makes her out-door stroke.

It must, however, be borne in mind that, although the steam pressure on both sides of the piston is equal, the steam is still in the cylinder, and must be withdrawn before the engine can make another stroke. To effect this the exhaust valve L is opened, the steam rushes along the eduction pipe M into the condenser N. Here the injection cock (not shown in the diagram) is opened, a jet of

cold water rushes into the condenser, and the steam is at once condensed. There is now again a vacuum under the piston and in the equilibrium pipe I, and the engine is ready to make another stroke as soon as the steam valve is opened.

126. Condenser.—The condensation of the steam in the condenser N, by means of cold water, results in the production of a quantity of hot water. There is also a quantity of air dissolved in the water and mechanically mingled with it, and this must be removed or the efficiency of the condenser will be impaired. The hot water, air, etc., pass through the foot valve O into the lower part of the "air pump" P. From here they are withdrawn by the air pump, the rod of which is shown at *r*, the bucket at *s*, and the cover valve at *t*. The upper part of the bucket is sometimes formed by a large circular valve as shown; and when the air pump rod descends, this valve opens and allows the hot water and air to pass upwards into the hot well which is placed at the upper part of the air pump. When the bucket rises the valve closes, and the water, etc., are raised and delivered through the cover *t*, which opens to permit their passage. When the rod descends, the cover valve opens again, and the air pump is ready for another stroke. To economise fuel the hot water so raised by the air pump is accumulated in the upper widened part of the air pump P′, from which it flows under the plunger of the hot water pump *u*, and is forced up to supply the waste from the boiler.

127. Valve Gear.—The different valves are worked by tappets placed on the plug rod *b*, but the small scale of the drawing does not allow of these being shown. The speed of the engine is regulated by means of the "cataract" T, which is placed under the floor *w w*, but the details of which are not shown. All the valves are made self-acting, *i.e.*, the working of the engine is made to open and close the valves, but the engineer is able, by modifying the position of the tappets, and in other ways, to make the stroke of the engine as few as one in several

minutes, or as many as 13 or 14 in one minute as may be required, but the engine works most economically when making from 3 to 5 strokes per minute.

A pair of magnificent engines of this type were erected by Messrs. Harvey & Co., of Hayle, in Cornwall, for the Tyne collieries, in 1869. The diameter of the cylinders is 100 inches, the length of stroke 11 feet, weight of main beam 40 tons, and the total weight of each engine nearly 200 tons. Such great masses cause the first cost of such machines to be very great, but this is more than made up by the rarity of stoppages for repairs and the daily economy of working.

128. Duty of Engines.—There are many ingenious contrivances in connection with the best Cornish engines, which have for their object the saving of fuel, or the more perfect working of the engine. These cannot be described here, but the result of their combined use is, that several good Cornish engines are now at work continuously, both in mines and in water-works, whose "duty" averages nearly, or quite, 100,000,000 foot-lbs., or in other words, which lift one hundred million pounds of water one foot high, by the consumption of each hundredweight of coal.

This high duty is obtained when the engines are large, do not work too rapidly, and are supplied with steam at from 40 to 50 lbs. per square inch pressure from an abundant boiler space. Generally, it will be better to use an additional boiler for supplying steam in preference to forcing those already in use beyond their capacity.

129. Compound Engine.—A different mode of working steam expansively was introduced by Arthur Woolf, many years ago, in Cornwall, and after being worked some time by Sims and others, was at length abandoned. The mode adopted was to use two cylinders, one much larger than the other; the small one placed sometimes above, sometimes within, the larger. Steam at high pressure was admitted to the smaller cylinder; and, after doing its work there, instead of being discharged to the condenser, was allowed to flow into the large cylinder where it ex-

panded so as to fill it, at the same time pressing down the large piston with a certain force. The motion so produced was transmitted through the piston-rod to the main beam of the engine, and from there to the pump rods in the ordinary manner.

The greater complication of two cylinders, two pistons, and a double set of steam passages, led to the abandonment of this mode of applying steam expansively in favour of that described in the last section, but a modification of this compound engine principle is now being introduced with much success for marine and stationary engines, and with great economy of fuel.

130. Boilers.—Among the boilers most suitable for supplying large volumes of steam continuously at the pressure named, may be mentioned those which are known as the "Cornish" and the "Lancashire." The Trevithick or Cornish boiler is illustrated in figs. 68 and 69. Fig. 68 is a perspective view of the boiler, fig. 69 is a section

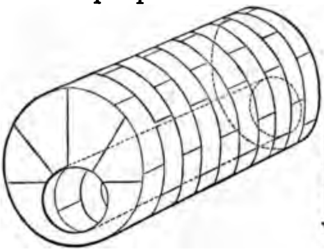

Fig. 68.

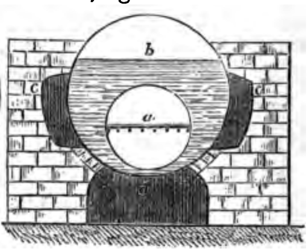

Fig. 69.

showing the mode of setting. The boiler consists of a cylindrical shell made of boiler plates strongly riveted together. This is riveted to the flat ends, and the angles strengthened inside by "angle-irons." A cylindrical tube is riveted in the same manner to the flat ends, but nearer the bottom of the shell than the top. The fire bars are placed in the tube, as shown at *a*, fig. 69, and the space around the tube is filled with water up to the water line *b*. The boiler is supported by masonry en-

closing the flues at *c c* and *d*. The flames and heated air produced at *a* pass along the boiler, return to the fire end by the side flues *c c*, and being then directed into the bottom flue *d*, pass along under the boiler to the chimney which is placed at the far end. The effect of this arrangement is that most of the heat of the fire is imparted to the water in the boiler before the products of combustion make their escape up the chimney or "stack." Many Cornish boilers are made from 30 to 40 feet long, and 7 or 8 feet wide, with a fire tube from 3 feet 6 inches to 4 feet 6 inches diameter; and some large engines require as much steam as can be supplied by three, four, or even six of such boilers.

When large boilers of the Cornish type are used, it is desirable to strengthen the fire tube by rings, transverse tubes, or in some other manner.

The Lancashire or double flued boiler, as shown in fig. 70, is really a modified Cornish boiler, in which a somewhat larger heating surface is obtained with equal water and steam space without increasing the size of the outer shell.

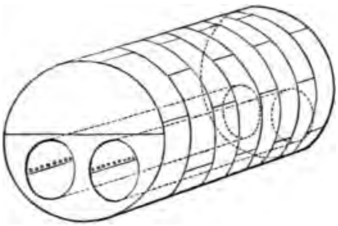

Fig. 70.

131. Clothing of Boilers, etc.—Much of the economy of the Cornish system of pumping is no doubt due to the careful manner in which the boiler, steam pipes, cylinders, valves, etc., are encased in steam jackets, or clothed with felt, sawdust, or other non-conducting material. In many cases the temperature of the engine house is uniformly below 90°, except in very hot summer weather, and the boiler houses are but little warmer.

132. Quantity of Water Raised.—The quantities of water to be raised in some mines are immense, as the following example will show.

At Mellanear Copper Mine, near Hayle, by no means a very extensive mine, during the month of April, 1873, and for many months previously, no less than 1162 gallons of water per minute were raised, chiefly from the bottom of the mine. In some mines the quantity raised has reached, for short periods, the enormous quantity of 3000 gallons per minute. In 1837, the late Sir Charles Lemon estimated the quantity of water raised from the mines of Cornwall at 37,000,000 tons.

133. Direct Acting Pumps.—Within the last few years a totally new mode of forcing water from deep mines has been adopted in some districts with considerable success. The pumping engine is placed at the bottom of the mine itself, and supplied with steam by a clothed steam pipe, the boilers being placed above ground. The piston-rod has a piston at one end and a ram at the other. The piston works in the steam cylinder, the ram is a force pump, or water cylinder, which communicates with the sump or storage cistern. From the force-pump a rising main proceeds direct to the surface, and as water is forced by the motion of the ram in both directions, the steam is constant instead of being intermittent, so that for a given quantity of water a smaller diameter of pump is amply sufficient. These "direct acting" pumps, as they are called, which are made by Messrs. Tangye, Hayward Tyler & Co., and others, work with considerable economy, considering that the steam is used non-expansively, and their first cost is very low; the chief drawback, in districts where fuel is cheap, is in their situation at the bottom of the mine, since in case of accident the engine itself would be drowned out. It is therefore necessary to have these pumps in duplicate, or nearly so, or a serious risk is encountered.

One of these pumps was used for a long time, and with much success, in 1872, for pumping water *into* the Morfa Colliery, in South Wales, in order to put out a great fire which resulted from a most disastrous explosion.

CHAPTER XVII.

ON ORE DRESSING OPERATIONS.

134. The ores having been brought to the surface by some of the modes described in Chaps. XIII., XIV., it is necessary to separate them from the worthless material or gangue. To some small extent this is occasionally done underground, especially in the case of the ores got by tributers, but the principal part of the separation or "dressing," as it is called, is always necessarily done at the surface.

The dressing operations differ much in the case of different ores, not only in the modes adopted, but also in the more or less complete separation of the veinstone, or gangue. Tin ores are dressed up to a very high standard, often so as to yield 70 per cent. of metal. Lead ores, as commonly sold, contain from 60 per cent. downwards to 15 per cent. Copper ores from 18 or 20 down to 3 or 4 per cent. Manganese ores are valued according to the proportion of peroxide, varying from 50 to 90 per cent.; a standard of 70 per cent. is adopted, and the value rises much more rapidly for every additional per centage of peroxide in the case of rich than of poor ores. Iron ores are simply spalled and hand-picked in general, and yield, as sold, from 25 to 65 per cent. of metal, according to the kind of ore. Ores of gold, silver, and other valuable metals, are often treated by a combination of mechanical and chemical operations, sometimes of a highly refined character. In this elementary treatise, we must confine ourselves to a descriptive outline of the modes adopted in preparing the ores of tin and copper for the market in Cornwall, and of silver ores in South America.

135. Tin Ores.—The ores, if in large masses, are first "spalled," or broken up by means of heavy "spalling hammers," and this affords an opportunity for picking out the larger portions of the gangue. Generally, the

result of the spalling process is the production of a pile of best ore, a pile of seconds, which is separately treated in its further stages, and a pile of "deads," which is thrown away.

Sometimes after spalling the ore is taken at once to the "stamps," but occasionally it is broken or "cobbed" still smaller by means of lighter "cobbing hammers," and this gives another opportunity of hand picking. In mines yielding large quantities of stuff of even quality, so that hand picking is of little avail, the spalling and cobbing processes are now sometimes superseded by the use of a stone breaker or crusher, "Blakes" being preferred. The economy of this, when the tin-stuff is hard, is very considerable, probably about one-half, since the cost of hand spalling is from 6d. to 8d. a ton, while the stone breaker will do the same work for 3d. or 4d., which sum includes a full allowance for depreciation of the machinery, and interest on its first cost.

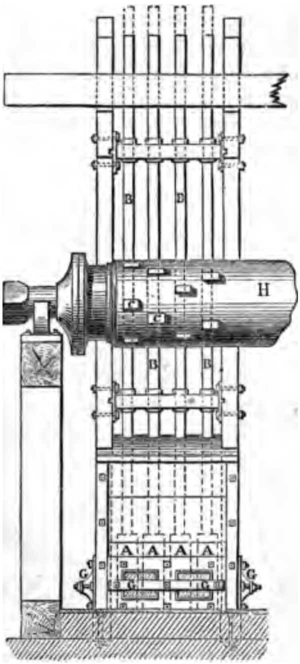

Fig. 71.

136. Stamps.—The ore being broken down about the size of road stone, is now in a fit state for the action of the "stamps." Those in ordinary use are shown in figs. 71 and 72. The ore is tipped on to the slope *D, fig. 72,* and gradually makes its way down

under the heavy stamp heads A. These stamp heads, weighing from 4 to 6 cwt. each, figs. 71, 72, are lifted successively by means of the lifters B, and the cams *c* on the revolving axle H, to a height of 10 or 12 inches, and falling on the ore speedily reduce it to fine powder. Water is continually falling upon the ore from a "launder," as shown in fig. 71, and this facilitates the escape of the fine particles of ore through the gratings or "stamp grates," G G. Taking the county of Cornwall throughout, the average weight of the stamp head and lifter will perhaps be 4 cwt., the number of blows per minute about 40, and the amount of stuff stamped not far from 1 ton per head in each 24 hours. The average consumption of fuel, when steam engines are used, is about 1½ cwt. per ton of stuff.

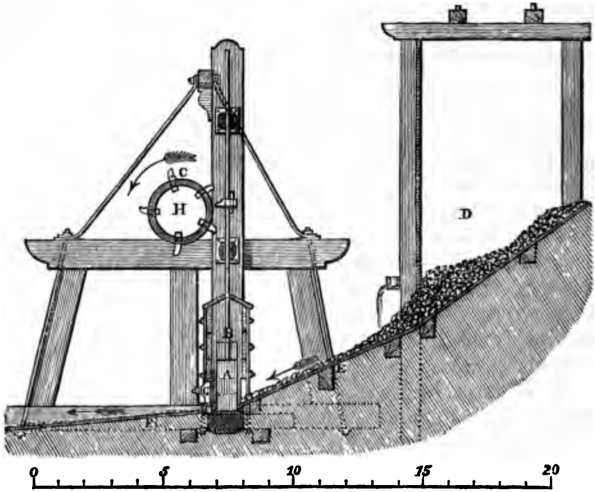

Fig. 72.

In the copper mines of Lake Superior, in the silver mills of Nevada, and in the gold fields of Australia, much

heavier stamps are in use, in some instances nearly a ton each, and the work got through is increased in an even greater proportion, but special contrivances are necessary to guard against "over-stamping," by providing for the free exit of the ore as fast as it is sufficiently reduced, as, if this is not done, a large amount of "slime" ore is produced, resulting in much loss of ore in the subsequent dressing processes.

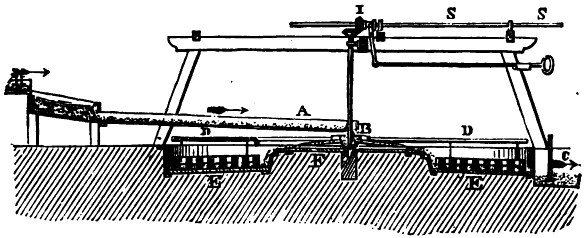

Fig. 73.

137. Buddling.—The finely-powdered ore, passing from the stamp grates, is treated in a variety of ways, in buddles, frames, kieves, etc., but the aim and end of all these operations is the same, viz., the separation by the action of gravity of the heavy ore from the lighter waste, the different specific gravities being aided by partially suspending the ore in water. In the present treatise we can do little more than describe one of these processes, that of "buddling." Fig. 73 is a section of the ordinary convex buddle. E E is a circular pit about 18 or 20 feet in diameter, and 2 feet 6 inches deep at the sides. F is a raised table, 5 or 6 feet in diameter, highest in the centre, and sloping outwards in all directions; the floor of the pit E E also slopes outwards as shown. The stamped ore suspended in water, forming a very thin mud, passes in the direction of the arrows into the hopper at A, and is strained through a grating which keeps back any chips of wood or coarse waste which may have got into the channel. The ore passes down the channel A in the

direction of the arrow, and flows into the cup B of the central table, and from here is distributed by six or eight openings or channels over the central table, and from here over the floor E of the buddle. D D are brushes four or six in number, which revolve and spread the ore evenly over the floor of the buddle. The whole is moved by the level wheels I, by means of shafting *S S*, communicating with a water wheel, or some other source of power. It is found that, by buddling the stamped tin-stuff in this way, the heavier particles of ore mostly accumulate near the central table, while the waste is chiefly carried by the flowing water to the circumference. The buddle being full, the outer portion is thrown aside or buddled over again, and the central portion in like manner is treated by itself, either by repeating the same process or slightly varying it. Other forms of buddles are in use; in some the central part is made lower than the outside, and the ore is supplied around the circumference, but the principle of all buddles is the same.

The "frames" are sloping, wooden trays often self-acting, and generally used for dressing very fine ores or "slimes." The ore is made to run down the slope, when the richer portions remain on the wooden surface of the frame, while the light waste is carried away by the water. These richer portions are at intervals washed into separate receptacles by a sudden flush of water.

When the ore is thus rendered tolerably pure, it is placed in quantities of several cwts. in a large tub or "kieve" and well stirred up with water. It is then allowed to settle, while a continual vibration is produced by knocking with hammers against the sides of the kieve. When at last the ore has all settled down, the water is poured away, and the upper layers of the deposit are scraped off and put aside for further treatment, as they contain nearly all the remaining impurity. This operation is called "tossing" or "tozing," and the ore is now ready for sale as "black tin."

138. Calcining.—The methods just described are suffi-

cient when the water is, as is usually the case, much lighter than the ore. Sometimes, however, the waste consists of pyrites, mispickel, or some other metallic mineral, when an additional operation is necessary, called "burning" or calcining. The partially dressed ore is placed in a furnace and strongly heated. By this heating the oxide of tin is not changed, but the pyrites or mispickel gives off its sulphur or arsenic as a thick smoke, and is changed into oxide of iron, which being much lighter than oxide of tin, is readily washed away by the buddling or other dressing operations. The fumes of sulphur or arsenic are condensed in long flues, from which they are collected at intervals and sold.

In the various processes a quantity of material of a mixed nature, called "dredge," or "roughs," or "rows," is often separated, on the one hand from the rich ore, and on the other from the worthless waste. These "rows," when examined under the microscope, are seen to be of a compound nature, consisting of particles of ore attached to particles of waste. In order to separate these different materials, it is necessary to reduce the "rows" to a very fine powder, and this is best done by machines called "pulverisers." The material to be treated is mixed with water, and ground between plates of iron moving rapidly in opposite directions, after which it is dressed on buddles or on frames like the "slime" ores already mentioned.

139. Copper Ores are, in the first instance, spalled, cobbed, and hand-picked, as already described in the case of tin ores, and divided into "best work" and "seconds," which are treated separately in the subsequent processes. They are then passed into the crusher, which consists of two short and heavy rollers of chilled iron, moving in opposite directions, and kept in contact by means of a weighted lever. The ore is fed into the crusher through a hopper, and in passing between the rollers is broken into small fragments. The crushed ore passes into a revolving cylindrical sieve or riddle, the wires of which are about $\frac{1}{2}$ or $\frac{5}{8}$ of an inch apart, and the pieces which

are too large to pass through are returned to the hopper. The best ore when so crushed is ready for sale, but the seconds has next to be "jigged." In this process the ore is spread over the bottom of a large rectangular sieve, the wires of which are from $\frac{1}{4}$ to $\frac{1}{8}$ of an inch apart. The sieves are made to move up and down for a few minutes with a peculiar jerking motion while dipping in water. The fine particles which pass through the sieve are sometimes buddled, sometimes sold without further treatment. The effect of the jigging upon that which remains in the sieve, is to cause the richer particles of ore to form a layer near the bottom, the lighter waste resting upon it. This is scraped off and thrown away, or put aside for further treatment, but the lower layer is found to be so much enriched as to be now ready for sale.

140. Lead Ores are usually dressed to a higher standard than copper ores, but the mode adopted is very similar. The slimes are ground and buddled, and treated like tin ores.

141. Sampling and Assaying.—Tin, copper, and lead ores are often got by tributers as already mentioned, and in such cases it is necessary to carefully sample the piles or "doles" belonging to the different parties before they are thrown together for dressing. The mode of doing this is as follows:—The whole heap is first well mixed, and then divided into four equal portions. One of these portions is taken, and all the large pieces are broken up small, spalled, and cobbed, and again well mixed. From this another fourth is taken and broken still smaller, and again mixed and divided, and these operations are continued until the portion operated is reduced to a fine powder. A weighed or measured portion of this is then taken for or by the sampler for assay. If a tin ore, the produce is at once determined by the process of vanning, and sometimes this mode is adopted for copper or lead ores. More commonly, however, these are assayed by heating in a clay crucible with the proper fluxes, and the tributers are *paid for the whole* pile, which is weighed before being

dressed, according to the result of the assay. In general the tributers find it is to their advantage to divide their piles into two, separating the best work from the seconds, when each portion is of course separately assayed.

142. Gold and Silver Ores, Amalgamation.—Gold very frequently occurs in the state of metal, when it is usually separated by stamping, and a series of washings somewhat like the mode adopted in dressing tin. Both gold and silver, however, often occur in small proportions, chemically combined with other substances, when the process of amalgamation is adopted for their separation. At Chontales Mine, in Nicaragua, the gold and silver ore is first stamped fine, and then allowed to pass successively over amalgamated copper plates, "riffles," or small stony channels containing mercury, channels or boxes filled with mercury and blankets, and finally through a copper plated launder into a rectangular buddle. The plates are prepared by first washing with nitric acid and then rubbing with mercury, a little sodium being added to the mercury to increase its attraction for the precious metals.

The plates are scraped every twelve hours, and the amalgam so obtained, as well as that found in the riffles and mercury boxes, is washed with water to clear it from all grease, sand, or other impurity. All the washings of the first amalgam, the washings of the blankets and the stuff from the head of the buddle are then ground fine in the "arrastre" or "tahona," a rude mill of rough stones worked by mules, mercury is added from time to time, and the amalgam so obtained is added to the first portion. The whole is then squeezed through sail cloth or leather to separate any excess of mercury, and the remaining amalgam is placed in an iron retort and strongly heated. The mercury from the amalgam passes away as vapour, and is condensed in vessels of cold water for future use, and the alloy, gold and silver, remaining in the retort, is run into bars for sale; these métals being afterwards separated from each other by a separate chemical process. In Mexico it is the practice to grind the ores very finely

with mercury or amalgam in arrastres, after which a crude sulphate of copper obtained by roasting copper pyrites is added, together with common salt and more mercury, and the whole being well mixed is left to a kind of fermentation for several days, when the amalgam is separated by washing and the mercury separated in the manner already described.

143. Many modifications of this amalgamation process are adopted in different mines, districts, or countries; but the broad outlines of the process are everywhere the same. The loss of mercury is considerable, but varies from half an ounce for each ounce of the precious metal obtained up to four or five times that quantity.

CHAPTER XVIII.

ON THE VENTILATION AND LIGHTING OF UNDERGROUND WORKINGS.

144. **Nature of Air.**—No miner can be too much impressed with a sense of the great importance of good ventilation. The air we breathe consists mainly of two gases called by chemists "oxygen" and "nitrogen." These are mingled together in the proportion of about one part oxygen to four parts nitrogen. It is the oxygen which is really necessary for the support of life, while the office of the nitrogen is to dilute it and to increase its volume. The air being taken into the lungs in the act of breathing, the oxygen combines with some spent carbon from the blood, and is thereby converted into "carbonic acid," or as it is sometimes called "carbonic anhydride." Carbonic acid is injurious when breathed, even if it is mixed with a large volume of pure air, and it should therefore be removed as fast as it is formed. When men work in the open air the carbonic acid formed is speedily dispersed, and as the supply of pure air is

abundant, no ill effect follows. But it is otherwise in rooms, and especially in mines; here the air soon becomes quite unfit for use if it be not constantly renewed, hence the necessity for ventilation.

The impurities imparted to the air by breathing are much increased in mines by the constant use of candles or lamps, rendered necessary by the absence of daylight, and by the explosion of powder or other agents used for blasting. In some iron mines, carbonic acid is given off in large quantities by the ore as it is broken, and in many metal mines, where iron pyrites is abundant, the air is speedily deprived of its oxygen and rendered unfit for use, and incapable of sustaining life by the oxidation of the pyrites which is continually going on. In coal mines, inflammable gases called "fire-damp" are often given off in great abundance, but such gases are very seldom met with in metal mining, except in coal districts.

The miner has always a good test at hand for the fitness of the air he is breathing. If his candle burns brightly and well the air is fit to breathe, but if he has great difficulty in keeping it alight when the air is still, or if the flame becomes larger and of a pale blue colour, and flickers greatly or goes out, the air which does not properly support combustion will not support life, and some artificial means of ventilation becomes necessary, or the miner's health will give way.

This test is much more reliable than the common mode of judging by the rapidity of the current at any given point, as it may be applied in the working "ends" or "faces" themselves where the air is often stagnant, notwithstanding that there is a good current in some of the drifts.

145. Ventilation may be either natural or artificial. In coal mines it is almost always artificial, in metal mines it is in a majority of instances natural. Sometimes, however, the naturally produced current of air is improved and guided by air stoppings, doors, or other means as may be found necessary, and in some few

instances an entirely artificial mode has to be adopted, especially while sinking shafts or driving long levels.

Unless the shaft be very deep, a simple division of thin wood or painted canvas, dividing the shaft from top to bottom into two, will often be found sufficient. The men working in the shaft on one side of the parting will raise the temperature somewhat, when it will be converted into an upcast, while the cool air will descend on the other side or downcast to supply its place.

146. Air Sollars.—A natural current may often be produced in a long level by means of an "air-sollar." To form an air-sollar, the floor of the level carrying the tram road is laid about 6 inches above the actual bottom of the level, and is supported by cross-sleepers resting upon blocks of wood or stones, or the floor in the centre of the level may be excavated somewhat deeper than the sides. Planks are laid over the sleepers just mentioned to form a kind of deck, and the whole is rendered air-tight by plastering with mud. This will divide the tunnel into two very unequal portions. Through the lower division or air-sollar, a current of cool and therefore heavy air will pass into the end, and this will be further cooled if there be water issuing from the lode at any points. The air heated by the breathing of the men, the heat of the candles, etc., will pass out through the level itself, and so a constant current will be kept up. The "level" should be kept as truly level or "dead" as possible for several reasons, two of which may be mentioned here: 1st, if there be water flowing out through the level, and the fall be considerable, the rapidity of the current of water will, to some extent, check the ingoing current of air; 2nd, if the level rise rapidly, the floor of the end will soon be at a higher actual level than the "back" of the entrance, when the heated air will actually have to *descend* in order to make its escape, although the natural tendency of heated air is always to *ascend.*

147. Should it be necessary to do more than divide the *shaft, or air-sollar* the levels, the mode known as pipe

and cap-head, which is similar to that which is so commonly used on board ship, may be resorted to. This is effected as follows. A pipe of thin metal or 1″ wood is made of about 1 square foot area or less, to which is fitted a revolving cap-head *a*, fig. 74. The lower end of the pipe is carried down to the bottom of the shaft, and the open mouth *b* is turned towards the wind. A current of fresh air is thus forced down to the bottom of the shaft where the men are at work, and thus displaces the foul air, forcing it up the shaft. In Cornwall, for temporary purposes, the writer has seen a zinc rain-water pipe so arranged with a miner's jacket extended by wires at the top for a "cap-head" or "sail." A similar arrangement may be adopted for ventilating a level, the pipe being carried into the end, but sharp angles in the pipe should be avoided as much as possible. It is plain, however, that this mode of ventilation can only be adopted when the wind is blowing, but in time of calm, underground ventilation is most of all wanted. To meet this difficulty, a small fan may be placed in the upper end of the pipe, worked by hand, a water wheel, or a steam engine, and arranged either to force pure air into the workings, or still better, to draw the impure air out, leaving the pure air to find its way down the shaft.

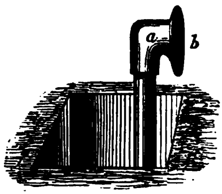

Fig. 74.

In many cases a jet of high pressure steam from a boiler may be discharged into the upper end of the pipe, when an outward current will be at once set up.

148. The Water Trompe.—Where there is a supply of water at surface, and an adit level to carry away the waste, the water "trunk," or "trompe," may be used for ventilation with much advantage. If there be no adit, and the spent water would have to be pumped up again after use, it may be better to apply the *power directly* to produce a current of air by

means of a fan or air pump, unless there be a surplus of pumping power. Figs. 75, 76 show two forms of the water trompe. In fig. 75 the water from the launder *a* falls upon the series of iron bars *b*, and down the pipe *c* into the cistern *d*. The stream of water being broken by the bars, a quantity of air is entangled and carried down with it, and this escapes at the trunk or exit pipe *e*. The water overflows the cistern *d* and is pumped up again, or passes away by an adit level. In fig. 76, the water enters the hopper by the launder *a*, passes

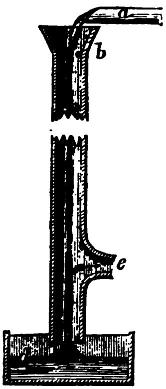

Fig. 75.

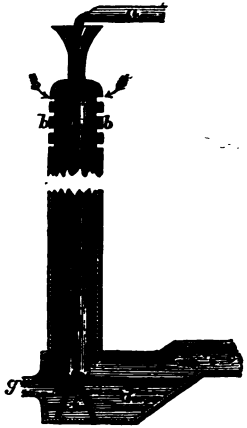

Fig. 76.

down the pipe *c*, and falls upon the dash-block *f*, placed in the cistern *d*, the overflow of which is at *g*. Air is drawn into the pipe *c* through the holes *b*, and makes its exit as before at *e*. By lengthening the exit pipe so as to reach into the "end" of a level, these modes may be made available for ventilating very long drifts. In all cases the exit pipe should be large, as it is quantity rather than a rapid current which is wanted, and sharp angles should be avoided as much as possible, since the

air current receives a serious check at every sudden change of direction.

149. **Natural Ventilation.**—In working lodes to a moderate depth, the difference of level of the "braces" of the different shafts, due to the irregularities of the surface, is often sufficient to determine the direction of the current of air, and to produce a good natural ventilation, although it is sometimes necessary to use air partings or stop doors to aid this. Thus, if in a mine, situated as in fig. 77, there be two shafts, *a b*,

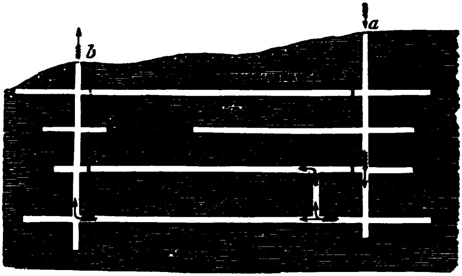

Fig. 77.

the current will be in the direction of the arrows when the surface temperature is warmer than that of the bottom of the mine, and it will be reversed when the surface temperature is lower. Whenever the surface temperature is the same as that of the bottom of the mine, the ventilation will be likely to suffer; but this state of things will not last many hours at any one time, since the temperature of the bottom of the mine will be constant, that of the surface rapidly variable. It may be necessary to place regulating doors at *b b* and *c c*, *bb* being shut when *cc* are opened, and *vice versâ.* At *d* the current will be divided as shown. The level at *e* will be very badly ventilated unless a current of air can be sent along it by means of an air-sollar, or in some *similar manner.* Sometimes a chimney is built over one

shaft to increase the natural inequality of level, and to assist in the determination of the current. This should be of large area, as if small, a sufficient quantity of air will not pass.

In very deep mines the difference to be obtained by means of a high chimney is very slight as compared with the whole depth of the shaft, but the naturally high bottom temperature of such mines greatly assists their ventilation by means of natural currents.

150. Heat of Deep Mines.—The rate of increase of temperature in deep mines varies much in different localities. In some places it has been found as much as 1° F. for each 45 feet in depth, in others little more than half this rate. After about the first 10 fathoms the variations of surface temperature have no effect on that of the mine below, which, in the absence of chemical changes or of hot springs, is always almost exactly the same. One exception, however, must be noted. In deep workings, when they are first opened, the temperature is often much higher than in the same situations after several months' working. Thus, at the Clifford Amalgamated Copper Mines, in Gwennap, the air in the 220 fathom level was 100° F. in 1863; but in July, 1864, it had sunk to 83°. In the 230 fathom level then just opened the temperature at the same date, July, 1864, was 104° F.

At the Duckinfield Colliery, in Durham, the temperature was found to increase from a depth of 20 feet down to 358½ fathoms, at an average rate of 1° F. for each 88 feet in depth. At the Rose Bridge Colliery, near Wigan, from a depth of 80½ fathoms to 403 fathoms, the average increase was at the rate of 1° in each 67 feet. This latter is one of the deepest mines yet worked.

Perhaps the greatest depth yet attained is at *Viviers Reunis*, near Gilly, in Belgium, where the shaft itself reaches a depth of 3411 feet, or nearly 570 fathoms, and the bottom of a *trial-staple* was found by Mr. W. W. *Smyth, in 1871,* to be 3489 feet, or 581½ fathoms.

Furnaces, air pumps, or powerful steam jets are seldom required in the ventilation of metal mines, unless they are situated in coal districts, or worked in connection with coal mines. The construction and mode of working will be fully described in the elementary treatise on "Coal Mining," forming part of this series.

151. Lighting of Workings.—In the metal mines of Cornwall, South Wales, and the north of England, the usual mode of lighting the mines while at work underground is by means of tallow candles. Each man carries a tallow candle in his hand while walking along the levels, using a lump of clay as a convenient holder. The same lump of clay serves to fix the candle to his hat, while he is ascending or descending the shaft, and to attach it to the rock in a convenient position when the place of work is at length reached. The candles used in Cornwall have large wicks, so that a sudden current of air may not too readily extinguish them; and there are from 12 to 16 to the pound. In the north of England the candles used go from 20 to 30 to the pound; and formerly much thinner candles than these were used, but such very small candles are now seldom seen.

152. Lamps.—In some of the mines of the north of England, South Wales, and Scotland, and in Saxony and other parts of Germany, small metal lamps are used, in which colza, rape, or other oil is burnt. These lamps are made with a small hook for attachment to the miner's hat, and a spike which may be placed in a joint of the rock when the place of work is reached. The light given by such lamps is not equal to that of good candles, and this is probably the reason why they have not found favour in Cornwall; but the cost does not exceed from $\frac{3}{4}$d. to 1d. per shift or core of eight hours, which is about one-half the cost of candles. Within the last few years, lamps for burning paraffin and petroleum oils underground have been devised. The author has not seen any of them; but they are well spoken of, as they give a good light at little cost. Hitherto,

however, they have not been made to burn without much more smell than either oil lamps or candles.

153. Coal gas was first utilised in Cornwall, by Murdoch, in or about 1792, when he lit up his workshops at Redruth with gas. He had previously been in the habit of carrying a bladder full under his arm, which supplied a lighted jet in his night journeys across the moors of Cornwall, to the great alarm of the country folk. Two mines at least have been lighted with gas at different periods in Cornwall, but at present no gas is used for this purpose in the county. At Tresavean Mine, early in the present century, gas was used for lighting the shafts and some of the principal workings. The latest instance, however, was at Balleswidden, about the year 1866, when gas was carried down the shaft and into the levels and pitches where the men were at work, as far as the 120 fathom level. Where four men were at work one gas jet was found to give sufficient light for all, with less smoke and unpleasant smell than candles. The cost was officially reported to be only one-third that of candles; but for some reason or other the apparatus was ultimately removed. Coal gas is extensively used for lighting mines of all kinds in the north of England. Sometimes it is made at the surface, stored in a gasometer, and sent down by means of a fan blower, steam jet, turbine, or a water trompe. A current having a force equal to a pressure of 10 or 12 inches of water is found sufficient to carry the gas down to a depth of 150 to 200 fathoms, and to maintain sufficient pressure at the burners. In mines where furnaces are used for ventilation the retorts are sometimes placed over the furnace, and the gas is purified and stored underground.

In the United States a kind of gas is produced for mining and other purposes by forcing common air through benzoline. This gas is slightly heavier than air, so that no difficulty is experienced in conveying it underground, as is sometimes the case with coal gas. The first cost of the apparatus is much less than that necessary for the

production of coal gas, the complete arrangement for 100 lights only costing from £60 to £100. The forcing apparatus is a kind of clockwork, which is wound up each morning by one man in less than an hour, and the light is said to be quite equal to coal gas, or even superior to it. The cost for each light is about ½d. per hour. This would be too costly a light to supply to each pair of men; but not too costly for the lighting of shafts and main roads, or levels, or other fixed positions, where a constant light is needed. This mode of gas lighting is now to be seen in the International Exhibition at South Kensington (July 1874). It seems to be admirably adapted for mining purposes.

EXAMINATION QUESTIONS.

The numbers within brackets refer to the paragraphs in which the material for answering the respective questions may be found.

1. What branches of science are of especial value to miners? [3-7].
2. What is the meaning of the term "crust" of the earth? [8].
3. What do you understand by the terms stratified rock, unstratified rock, and metamorphic rock? [10, 11, 12].
4. What is "killas," and where is it found? [13].
5. What are the leading groups or "formations" of stratified, rocks? Describe the chief mineral contents of each [13].
6. How do the rocks called "Elvan" occur? Illustrate your answer by a sketch [15.]
7. What is the general influence of elvans upon mineral veins or lodes? [15].
8. What do you understand by the terms *mineral*, *ore*, and *rock?* [17, 18].
9. Mention six metallic minerals or ores, and state the proportions or percentages of metal they contain when pure? [19].
10. What are the most common non-metallic minerals or spars? [20].
11. Describe six different kinds of rock [21].
12. Describe the usual mode of occurrence of mineral lodes or rake-veins, and illustrate your remarks by sketches [22].
13. What do you understand by the terms pipe-vein, flat, carbona, and stockwerke [23-26].
14. What do you understand by the terms capel, stickings, or selvage? [26].
15. What is a "horse" of ground? [27].
16. What is the average width and underlie of the Cornish tin and copper lodes? [27].
17. What are right-running and what caunter lodes? [28].
18. What phenomena are observable frequently at the points of intersection of right-running lodes by caunters and cross-courses? [28].
19. Illustrate by a sketch the position of the hanging wall and foot-wall of a lode.
20. What is the mean bearing of the tin and copper lodes, caunters, and cross-courses in Cornwall? [28].
21. What are the indications which guide the miner in his search for minerals in untried countries? [29].
22. *What is the* gossan which frequently occurs on the backs *of lodes?* What lodes have frequently no gossan? [30].

23. Describe the process of costeaning [34].

24. State what you know of heaves. If in driving due east on a lode a cross-course bearing north-west was met with, and the lode was not found on driving through the cross-course, would you be more likely to find the lode by driving to the right or the left? [36].

25. Can any idea of the extent of a heave be formed by observing the size of the cross-course or cross-vein which heaves it? [37].

26. What is the difference between an ordinary heave and a "slide?" [39].

27. What do you understand by the terms "dead work" and "productive work?" [40.]

28. What is an adit level? Give particulars of any remarkable adits of which you have heard, or with which you may be acquainted [42].

29. What are "winzes," and with what object are they made? [42].

30. What are "shoots of ore?" Illustrate your answer by a sketch [42].

31. What are the ordinary dimensions of shafts in metal mines, and why are shafts in hard ground usually larger than in soft ground? [44].

32. Compare the advantages and disadvantages of "downright" and "underlie" shafts [45].

33. How are shafts "secured" in tender ground? Show by sketches the difference between different modes of shaft timbering [46, 47].

34. What are the sizes of ordinary levels in metal mines? [48].

35. How much run or fall is usually given to a level in which a tram-road is laid? [48].

36. Show by sketches the various modes of timbering levels [48].

37. Why is the "cap-piece" in timbering a level usually made shorter than the "stretchers," and why are the "legs" inclined? [48].

38. Compare the cost of "sinking" and "driving" in soft killas or clay ground, in compact killas or pick and gad ground, and in fair blasting ground [51].

39. Calculate the cost of timbering a level, in moderately soft ground, 7 feet high, 3 feet 6 inches in the cap, and 4 feet 6 inches at bottom [52].

40. Compare the advantages and disadvantages of the different modes of "overhand" and "underhand" stoping [54].

41. How are the walls of the lode supported after the mineral is removed [54].

42. What will be the average cost of stoping fair blasting ground? [54].

43. What are the advantages and disadvantages of the different forms of "tut work" as compared with "tribute work?" [55-57].

44. What are the directions of the chief "faults" in different mining districts? [60].

45. State the advantages of trial borings in bed mining [60].

46. What do you know of the different modes of executing trial borings, and of their relative cost? [61, 62].

47. What considerations should guide the miner in determining the position of shafts? [41, 44, 63].

48. Describe some approved modes of working beds of iron ore [63, 64].

49. What is the average cost of "getting" iron ore from the "headings" and "pillars" respectively of a bed mine? What minerals are found in beds of "alluvial" gravel? [69].

50. Describe some approved mode of working beds of tin gravel in the so-called "alluvial" mining without removing the overburden [65-68].

51. How would you work a bed of gravel for tin or gold when the overburden is only a few fathoms in thickness? [70].

52. State what you know of the so-called "hydraulic" mining [70].

53. What quantities of oxide of tin per ton of stuff have been found sufficient to pay cost in different districts and under different circumstances? [71].

54. How is China clay worked in Cornwall? How much stuff can one man bring down in a day of eight hours under favourable circumstances when aided by a stream of water? [72].

55. What is the usual cost of removing overburden? [73].

56. Describe in detail the process of boring holes for blasting in different districts [74].

57. How is a hole charged with gunpowder for blasting? [74].

58. What explosives other than gunpowder are in use? What advantages have these under certain circumstances? [75, 76].

59. Describe three forms of pick, giving sketches and stating weights and dimensions [80].

60. Describe three forms of hammers used by miners, giving sketches and stating weights and dimensions [81].

61. Describe the Cornish long-handled shovel, and state its size, weight, and price [82].

62. What are the relative advantages of the long-handled Cornish shovel, and the short-handled shovel used in the North of England under different circumstances? [82].

63. Describe the different forms of wedges or gads used in metal mining, giving sketches and stating weights [83].

64. Describe the ordinary "borers" used in metal mining [84].

65. Describe the "jumper," "tamping-bar," and "swab-stick" [84].

66. What are the tools used by miners in preparing timber for shafts and levels? [85].

67. In sinking a shaft below a given level, how should the men in the bottom of the shaft be protected from the fall of stones from above? [87].

68. What are "striking deals," and what is their use? [88].

69. Show by a sketch the mode of dividing an engine-shaft for pumping, winding, and ladder-way [88].

70. What is the usual mode of constructing ladders for use in mines, and how are they placed in the shaft? [89].

71. What are the usual lengths of ladders, and how far apart are the rungs or staves placed? [89].

72. Describe the construction of "shaft partings" and "sollars" [89, 90].

73. Describe some form of "safety catch." What are the advantages and disadvantages of such contrivances? [91].

74. Describe the Cornish man-engine [93].

75. Give an estimate of the cost of supplying a man-engine to a depth of 200 fathoms, with driving engine complete, and compare this cost with the amount of labour saved to the men in climbing from great depths [94].

76. What are the usual forms and weights of tram rails, and the gauges to which they are laid? Illustrate your answer by sketches [97].

77. Describe the wheel-barrow used in the Cornish mines [96].

78. What will be the weight of a tram-waggon of boiler plate of the usual construction, 42 inches long, 30 inches wide, and 18 to 20 inches high? How much iron ore will such a waggon hold? [97].

79. Describe in detail the construction of a "tackle," "windlass," or "jack-roll." What is its cost? [105].

80. What is a "kibble?" Compare the sizes and capacities of winze-kibbles, whim-kibbles, and engine-kibbles [99].

81. Describe the mode of preparing a shaft for running a "skip" [99].

82. What is the cost of a double skip road per fathom of length? [99].

83. Compare the cost of raising mineral from shafts of various depths by means of (*a*) a tackle worked by two men; (*b*) a one-horse whim or whipsey-derry; (*c*) a two-horse whim; (*d*) a water-wheel; (*e*) a steam engine [100].

84. Compare the relative advantages and disadvantages under different conditions of (*a*) kibbles; (*b*) skips; (*c*) cages [101].

85. Compare the relative advantages and disadvantages under different conditions of (*a*) chain; (*b*) hemp rope; (*c*) iron wire rope (*d*); steel wire rope [102, 103].

86. With a breaking strain of 8, 18, and 40 tons respectively, what working loads may be adopted for wire rope; will the same ratio between working load and breaking strain hold good in the case of hemp ropes? [104].

87. Why is a chain less suitable for drawing stuff from a deep than a shallow mine? [104].

88. Describe in detail the mode of constructing a horse whim; what is its average cost? [106].

89. Describe the construction of poppet heads, and give sketches in illustration of your answer. What will be the cost of poppet heads for whim drawing? [107].

90. Describe any methods of raising mineral by water power with which you may be acquainted [108, 109].

91. What is the cost of raising mineral by the water balance in North Wales? Under what conditions is this mode of raising mineral to be recommended? [109].

92. Compare the relative advantages of the Cornish winding engine, and the double cylindered horizontal engine [110, 111].

93. Describe with a sketch the common suction pump [114].

94. Make a sketch of a common "drawing lift," showing the situation of the "clack" and "doorpiece."

95. Make a sketch of an ordinary "plunger lift," showing the situation of the "clacks" [114].

96. What modifications would you introduce into pit work in the case of a mine containing water of a corrosive nature? [117].

97. In some mines the men are in the habit of allowing piles of stuff to accumulate in the levels; what are the objections to this practice?

98. Why should "levels" be driven truly level, or nearly so? [116].

99. Make a drawing of a good form of *tackle, windlass,* or *jack-roll,* with dimensions marked thereon.

100. State how much work may be done with a tackle by two men.

101. Make a drawing illustrating the working of a drawing lift, and describe the several parts; why is a drawing lift used while sinking? [114].

102. Do the same for the plunger lift [114].

103. Make a sketch with dimensions of a good form of tram-waggon or tub [72].

104. What measures may be taken without using machinery for improving the ventilation of a mine? [145-148].

105. What are the objections to "over-stamping" of ore? [136].

106. How are the "pumps" fixed together so as to produce an air and water-tight joint? [118].

107. What is the construction of a main-rod, and how are the secondary rods attached to it? Illustrate your answer by a *sketch [119].*

108. How is the main-rod secured to the engine beam or bob? [119].

109. What are the "catch pieces," and what is their use? [119].

110. When the weight of the pump-rods is more than is needed to force up the water through the "plunger lifts," how is the extra weight counterbalanced? Show by a sketch the construction of the contrivance adopted [119].

111. How is the direction of the pump-rods changed in shafts with varying underlie? [120].

112. What is the "duty" of steam engines? [129].

113. Describe the variations in natural ventilation at different seasons of the year [119].

114. Why is it not a proof of good ventilation in a mine to have a very rapid current of air in a small place? [115].

115. Describe the water blast or trompe, and give a sketch showing its mode of action [117].

GLOSSARY.

(See also Index for many technical names.)

Account-house, the house in which the captains or agents of a mine keep the accounts and superintend the workings.

Adit, the water level of a mine.

Adlings, earnings.

Adventurers, the owners of a mine, or the individuals who together form the mining company.

After-damp, the poisonous gas which results from an explosion of foul gas or fire-damp in a coal mine. It consists chiefly of the gas called carbonic acid, mingled with much steam. It is often called choke-damp, because it suffocates many of the men who may have been uninjured by the actual explosion.

Agents, the managers or overseers of a mine.

Air-machine, an apparatus for forcing fresh air into, or withdrawing foul air from, a mine. A ventilating machine.

Air-pipes, pipes for conveying fresh air into the levels.

Aitch-piece, that part of a plunger lift in which the valves or clacks are fixed.

Alabaster, a kind of gypsum.

Alloys, combinations of two or more metals with each other are so called. Thus *brass* is an alloy of zinc and copper, and *bronze* of tin and copper.

Amalgam, an alloy of which mercury or quicksilver is one of the ingredients.

Amalgamation, the mode of separating gold or silver from their ores by means of mercury.

Analysis, the act of determining the composition of an unknown substance. *Qualitative* analysis determines the nature, and *quantitative* analysis the proportions of the various substances.

Ancients. *See* "Old Men."

Anhydrous, minerals and other substances which are free from or do not contain water are said to be anhydrous.

Aqueous, watery.

Arch, a piece of ground left unworked near a shaft or in a stope.

Arenaceous, containing sand, or consisting principally of sand. Thus, sandstones are said to be arenaceous rocks.

Argentiferous, containing silver. Thus, those kinds of galena which contain a considerable proportion of silver are said to be argentiferous.

Argillaceous, containing clay, or of a clayey nature. Thus, clays, shales, and clay-slates are said to be argillaceous rocks.

Assaying, the art of determining the proportion of any given substance in an ore or mix-

ture. It differs from an analysis in only determining certain stated substances.

Attle, waste or rubbish. The waste or rubbish of a mine is called "attle" or "deads."

Auriferous, containing gold. Pyrites, or sands containing gold, are called auriferous pyrites, or auriferous sands.

Back, a slippery or clayey joint or division in a bed of coal or hard rock. Sometimes called a "face."

Back of a lode, the upper part or outcrop of a lode at the surface of the ground; or that part which is "above" the men in any level.

Back-shift, the second set of miners working in any spot each day.

Bal, a common Cornish term for a mine. It applies rather to the surface than the underground workings.

Balk. *See* "Nip."

Balland, a Derbyshire term for lead ore in a finely divided state.

Bank or **Benk**, the surface of any mine, called "grass" by Cornish miners. Also the place from which the miners are turning out coal.

Banksman, the man who receives the ore at the top of the pit.

Bargain, an agreement between any party of miners and the managers of a mine to work any stated point at a given rate.

Bar Master, an officer who superintends the lead mines of Derbyshire.

Barrowman. *See* "Putter."

Basaltic, consisting of or resembling basalt.

Bass or **Batt**. *See* "Bind."

Basset edge, that edge of a bed which appears at the surface. *See* "Cropping Out."

Bast, a miner's supply of food for eating during work hours, called also "crib."

Beans, small coals.

Bearer or **Biard**, a large piece of timber used to support the engine and pumps or other machinery in or over the engine shaft.

Beche or **Bitch**, a boring tool.

Bender, a piece of iron attached to barrels, etc., to which the pit-rope is affixed.

Bind, a quarryman's or collier's term for a dark slaty kind of hardened clay.

Binghole, a hole through which ore is thrown. A Derbyshire term.

Bit, the working end or steel tip of a borer, or the borer itself.

Black Jack, *See* "Blende."

Black Tin, tin ore ready for smelting.

Blasting, breaking away masses of rock by means of gunpowder or other explosives.

Blasting Cone, a conical plug of wood or metal, sometimes introduced into the upper part of a hole for blasting above the powder, to serve instead of tamping.

Blasting Needle, an instrument used in blasting.

Blende, an ore of zinc.

Blue Elvan, a Cornish term for greenstone.

Blue John, the Derbyshire name for fluor spar.

Bob, the beam of the engine.

Bonnet, the covering to the safety cage, to protect men from injury from falling stones, etc.

Bord, Board, Bord-gate, or **Brow**, any gallery in a mine which is driven across the "face" of the coal or ore.

Borer or **Borier**, the long tool or chisel used for boring holes for blasting in mines.

Bottoms, the lowest workings in a mine or in a level.

Boulders, large masses of rock of a somewhat rounded form.

Bowze, lead ore as cut from the lode.

Brakesman, the man in charge of a winding engine.

Brances, pyrites in coal.

Branches, small veins of ore in connection with a main or principal lode.

Brattice, a temporary partition made for the purpose of directing the currents of air in a mine.

Breccia, a rock made up of *angular* fragments of other rocks. When made of *rounded* pebbles it is called a conglomerate.

Brittle, anything easily broken. In mineralogy the term is used in distinction to "tough." Thus schorl is brittle and hornblende is tough.

Brood, the heavier kinds of waste in tin and copper ores.

Bryle, the traces of the presence of a lode at surface.

Bucket, the piston of a lifting pump.

Bucking, a method of breaking the poorer sorts of copper and lead ores into small fragments by means of flat irons, called bucking irons. It is now nearly superseded by crushing machinery.

Bucking Iron, the iron with which bucking is done.

Bucking Plate, an iron plate on which the ore is bucked.

Bucklers. *See* "Tacklers."

Buddle, a contrivance for washing impurities from stamped or finely-ground ores.

Buddling, separating ores from waste by means of the buddle.

Bunch, a rich deposit of ore of small extent.

Burden, the top or waste in stream-works, etc., which lies over the layer of stream-tin or other material sought for. The same word, or "over-burden," is used by quarrymen with reference to the waste which overlies the good stone in a quarry.

Burning, the operation of roasting an ore for the purpose of driving off sulphur, arsenic, moisture, etc. It is the same as calcining.

Burning-House, the place where the "burning" is conducted.

Burrow, a heap. The heaps of attle, deads, or waste thrown out from a mine are so called.

Butty, a person who contracts to raise ore from any given point in a mine at a certain fixed rate per ton, making his own arrangements with the miners.

Cage, a machine for raising miners or ore.

Cage, the barrel on which the rope is wound in a whim.

Calcination. *See* "Burning."

Cann, Kann, or **Kand**, fluor spar.

Capel, a very hard substance which often forms the sides of tin lodes. It frequently contains small quantities of tin ore.

Carbona, an irregular deposit of ore found in connection with some tin lodes in the west of Cornwall.

Casing, a wooden partition separating the footway from the other portions of a shaft.

Caunter, a mineral lode whose direction crosses that of the main lodes of a district.

Chert, a hard flinty substance found in connection with some limestone, and valuable for road-making.

China-clay, a white and pure kind of clay used in the manufacture of china. It is abundant in Cornwall and Devonshire.

China-stone, a white decomposed variety of granite containing little or no mica, which is much used for the finer kinds of pottery.

Chlorite, a soft green mineral which often accompanies tin and other ores.

Clack, the valve of a pump.

Claggy, sticky.

Clay Iron, an instrument of iron used for lining bore-holes with clay to prevent the gunpowder from becoming wet.

Cleat. *See* "Joints."

Cleavage, the property which many minerals and rocks possess of splitting more easily and perfectly in some directions than in others. In rocks the cleavage, when present, *is usually* much more distinct *and perfect than* the bedding.

Cleet, a wedge; also a strengthening piece of wood.

Cockle, the Cornish name for schorl or black Tourmaline.

Coffer, Cofer, or **Cover**, the box into which ore falls in order to be pulverised by the stamping mill.

Coffins, a series of long narrow workings, each one being about 6 feet deeper than the one next to it. This mode of working was formerly adopted in place of sinking shafts.

Conglomerate, a rock made up of rounded pebbles.

Coper, one who contracts to raise lead ore at a fixed rate.

Copper Pyrites. *See* "Chalcopyrite."

Core, the space of time during which miners remain underground at their work. In Cornwall this is usually eight hours. In many mines the men are divided into three parties, each working eight hours, so that the work is carried on uninterruptedly.

Corve or **Corf**, a square frame of wood for carrying or sliding coal or ore upon at the bottom of the mine. Sometimes called a "dan."

Costeaning, searching for ore by sinking shallow pits in likely places, and driving short galleries, or cross-cuts, from one to another.

Count House. *See* "Account-house."

Country, the rocks in which a lode may occur are in Cornwall called the "country."

Course, a vein. Thus men speak of a "course of ore," an elvan "course," etc.

Crab, a machine used for raising weights.

Crane, a machine for raising heavy weights.

Craze, coarse fragments of impure ore separated in a late stage of tin-dressing.

Creep, the raising of the floor of a bed mine after the ore is removed from the weight of the rocks above forcing the pillars left for support down into those below.

Crib or **Curb**, a frame of wood or iron forming the foundation of the lining or tubbing of a shaft.

Crib, a miner's luncheon.

Cropping out, the appearance of a lode or bed at the surface of the earth.

Crop-tin, the chief portion of the tin ore, which is separated from its waste in the principal dressing operations. The finer portions, which are carried away by the water, are called "slime;" and that which is too coarse is called "rows" or "roughs."

Cross-course, any vein consisting principally of quartz, whose direction is across that of the lodes in a given district.

Cross-cut, in metal mining, a gallery or level driven across the usual direction of the lodes, usually for the purpose of searching for a new lode or of connecting two known lodes.

Crowbar, a strong bar of iron much used as a lever in quarries and other places for moving heavy masses.

Calm, hard coal.

Cupreous, containing copper.

Cut, to intersect a lode is called cutting the lode.

Cutter, *see* "joints."

Damp, a miner's term for foul air. *See* "Fire-damp" and "After-damp."

Dan, *see* "Corve."

Dead Ground, a portion of the lode containing little or no ore.

Deads, *see* "Attle."

Derrick, a pulley for raising a kibble from small depths in which the horse simply walks forward.

Desuing, working away the country at the side of a lode so as to break ore easier. It is done when the lode is harder than the country.

Dial, a kind of compass used for taking bearings underground.

Dialling, the art of surveying by means of the instrument called the miner's dial.

Dip, the amount of slope of a bed or vein measured from a horizontal line. *See* "Underlie."

Direction, the point of the compass towards which any vein or lode tends is its direction. The same as bearing.

Disintegrate, to break up from the effect of decomposition.

Disseminated, sown or sprinkled. Minerals which occur in small particles throughout the mass of a rock are said to be disseminated. Thus tin ore is often found disseminated in granite.

Dole, a division, as one-sixth, one-eighth, and the like, of a parcel of ore.

Downcast, the downward current of air in a mine.

Dredge, very fine matter held in suspension in water.

Dresser, the person who undertakes the dressing of ores.

Dressing of Ores, the act of separating ores from waste matter and preparing them for sale.

Drift, any working underground which is horizontal or nearly horizontal.

Driving, working horizontally, either along or across the course of the lode.

Dropper, a branch or string which leaves the main lode on the footwall side.

Drum, a kind of cage upon which chains or wire ropes are wound.

Dry, a place fitted with warming apparatus for drying the miners' underground clothes.

Dues, the portion of the produce of a mine which is paid to the land-owner or lord of a mine in lieu of rent.

Duty of Steam Engines, the amount of work done by any engine by the consumption of 1 cwt. of coal.

Dyke, a course or vein of igneous rock; a fault.

Elvan, The Cornish name for veins or courses of a kind of porphyry which sometimes extends through the country in the manner of a lode for many miles.

End, the extreme point of any level, at which the men must work in extending it further.

Engine Shaft, the shaft by which the drainage water of the mine is raised up to the adit *or surface*.

Face, *see* "joint."

Fathom, 6 feet. In metal mines all distances are reckoned in fathoms.

Fault, a disturbance of the strata, as shown in figs. 22, 23. When the displacement is horizontal, it is usually called a *heave* by miners; if upwards, a *leap* or *upthrow;* if downwards, a *slide* or *downthrow.*

Feather, an instrument used in wedging off masses of rocks. *See* "Plug and Feather."

Feeder, a branch, when it falls into the lode on the hanging wall side.

Feigh, the refuse washed from lead ore or coal.

Felspar, a mineral harder than calcite and softer than quartz, which breaks readily into fragments, having smooth sides at right angles to each other. It forms a considerable proportion of all granites and some other rocks.

Ferruginous, containing iron.

Filler, the man who fills the kibble, or skip, with ore at the bottom of a mine.

Fissure, a crack. Most geologists consider that lodes are simply fissures, originally formed by earthquakes or other causes, but now more or less completely filled with ores and veinstones.

Flat rods, pump rods arranged to work horizontally or nearly so. It sometimes happens that an engine placed over one shaft of a mine is required to work the pumps which extend down another shaft at a considerable dis-

tance. In such cases the connection is made by means of horizontal pump-rods or "flat rods," running upon rollers to lessen friction.

Flint, a variety of the mineral quartz, which is abundant in chalk rocks.

Flookan or Flucan, a cross-vein which is filled with clayey matter. Flookans which run parallel with the lode are sometimes called "course-flookans."

Flux, anything added to an ore so as to render it more readily fusible.

Foot-wall. *See* "Walls of a Lode."

Footway, the series of ladders and sollars by which men enter or leave a mine. They are sometimes called "way-gates" or "climbing shafts" in the North of England.

Fork, in Cornwall, the bottom of the sump, which see.

Fork, in Derbyshire, a piece of wood used to keep up the side of an excavation in soft ground.

Foundershaft, the first shaft sunk in a mine.

Frame, an inclined board over which a gentle stream of water is made to flow, for the purpose of washing away the waste from small portions of ore which are placed upon it from time to time.

Freestone, any kind of compact stone which may be worked freely. In some cases sandstones are called freestones, but more properly the name *should be restricted* to such soft stones as Bath-stone, Painswick-stone, etc.

Friable, anything that may be easily reduced to powder.

Fuse, a kind of combustible cord used for firing powder in blasting.

Fuse, to melt. Substances which may be readily melted are said to be fusible.

Gad, a kind of wedge used in breaking down small masses of rock in mining.

Galena, the most common ore of lead.

Gallery, a level of a mine.

Gangue, the valueless material, or "veinstuff," in which the ores of metals occur, or with which they are often mixed.

Gate, a road or way underground.

Gin, a machine for raising coal or ore from a mine. A whim.

Girdle, a thin layer of stone. Newcastle term.

Gneiss, a foliated rock composed of quartz, felspar, and mica. It differs from granite in these minerals occurring in distinct layers.

Goaf or Gob, the old deserted workings of a mine, often filled up with rubbish. In coal mines the goaf often contains a dangerous accumulation of gas.

Goffen, a long and narrow surface-working, perhaps connected with *coffin* and *goaf*, which see.

Gossan, the upper decomposed portion of a lode. It usually consists of a mixture of cellular quartz and oxide of iron, and often extends to

great depths in copper lodes. Also a kind of fault.

Grain Tin, the purest kind of metallic tin.

Granite, a crystalline rock composed of quartz, felspar, and mica.

Grass, the surface of a metal mine. Thus miners are said to come "to grass," when they come up from underground.

Grate, an iron plate punched full of small holes through which the stamped ore passes from the coffer to the dressing apparatus.

Gravel, small waterworn stones.

Grey Ore, a very valuable ore of copper.

Growan, a kind of coarse sand produced by the decomposition of granite rocks. Lumps of granite are sometimes called hard growan.

Guides, a local name for certain cross veins in the west of Cornwall.

Gunnies, abandoned levels or workings.

Hack, a large pick used for working stone.

Hade, Hadeslope, the underlie or inclination of a lode.

Halvans, the refuse heaps of mines, which still contain a small portion of ore, the residue of the dressing processes.

Hanging-wall. *See* "Walls of a Lode."

Hauling, raising ore or waste out of the mine.

Header, *see* "Joints."

Heading, a small gallery driven in advance of a gate road, or for any temporary purpose.

Hematite, red hematite and brown hematite are valuable ores of iron.

Hitch, a small fault which does not exceed the height of the bed or seam. *See* "Fault."

Hole, to hole is to make a communication from one part of a mine to another. Thus a level is sometimes driven at the same time from two shafts so as to meet or hole a point between the two.

Homogenous, of equal composition throughout. Applied to minerals.

Horse, any piece of "country" included within a wide lode; or two branches of a lode is called by metal miners a "horse" or "horse of ground."

Huel or **Wheal**, the Cornish name for a mine.

Hushing, the forcible washing away of the surface soil and sub-soil on a hill side, by a stream of water, for the purpose of laying bare the mineral deposits. It is adopted where water is abundant instead of costeaning.

Hydrous or **Hydrated**, containing water.

Indicator, an instrument for showing the position of the cage or skip in the shaft.

Indurated, hardened.

Infusible, anything which cannot be "fused" or melted.

Irestone or **Ironstone**, a Cornish term for greenstone, given on account of its extreme toughness.

Jack, a miner's term for zinc blende.

Jigging, a method of dressing poor copper and lead ores by shaking them with a peculiar motion in a kind of sieve which is made to move up and down in water.

Joints, natural divisions in masses of rock. They are variously called backs, cutters, faces, cleats ends, etc., according to their relative positions, the locality, and the material in which they occur.

Judge, a staff used for underground measurements.

Jumper, a tool used in quarries for the purpose of boring holes for blasting.

Junction, the point at which two veins meet.

Kann or **Cann**, a Cornish miner's term for fluor spar.

Keeper, an overlooker.

Keel, a large boat used for carrying ore.

Kevil, a sparry substance found in the Derbyshire lead veins, composed of calcite, fluor, or barytes.

Kibble, a kind of iron bucket used in many metal mines for raising ores.

Kieve, a large tub of wood or iron used for tozing tin ore before selling.

Killas, a Cornish miner's term for all kinds of slaty rocks.

Kit, a wooden vessel.

Knots, small particles of ore.

Lander, the man who receives the loaded kibble or skip at the mouth of the shaft.

Laths. *See* "Sets and Laths."

Launder, a gutter of wood or metal used for conveying small streams of water from place to place.

Leader, a branch of ore which if followed up often leads to the main lode with which it is connected.

Leadings, small sparry veins in the rock. A Derbyshire term.

Leap. *See* "Fault."

Leat, a water-course.

Leavings, waste heaps resulting from the dressing of ores.

Levels, galleries driven along the lode, in Cornwall usually at depths of ten fathoms below each other.

Lewis, an instrument of iron used for raising heavy blocks of stone.

Lifters, the upright beams to which the heavy stamp-heads are attached for stamping ores.

Limestone, any stone consisting chiefly of carbonate of lime.

Limp, an instrument of iron used for striking the refuse from the sieve in washing ores.

Loch, a cavity in a vein, a vugh. Derbyshire term.

Lode, a vein of any metallic ore.

Lord, the owner of the land in which a mine is situated is called the "lord." He receives generally a portion of the produce of the mine, in lieu of rent. This is called the "lord's due." It is frequently one-fifteenth of the produce of the mine in Cornwall.

Mallet, the hammer used in striking or "beating" the borer.

Man-engine, a machine used for raising and lowering miners.

Material Man, the man who has charge of and deals out the materials.

Matrix, the substance in which any portion of ore occurs embedded.

Mattock. *See* "Pick."

Maul, a large hammer or mallet.

Mear, 32 yards of ground measured on the vein.

Metalliferous, containing or yielding metal or ore.

Metallurgy, the art of extracting metals from their ores.

Micaceous, containing mica, or occurring in thin scales like mica.

Mineralised, containing particles of some "metallic" mineral.

Mock Lead, blende.

Moorstone, loose masses of granite which are found lying upon the moors in Cornwall.

Mundic, the Cornish and Devonshire term for iron pyrites.

Needle, a piece of stout iron wire used to make a hole through the tamping of a hole down to the gunpowder, to serve as a touch hole. It is called a pricker in many places.

Nip, a sudden thinning of a seam of coal or ore.

Noger, a jumper, borer, or drill.

Nogs, square blocks of wood which are piled one upon another to support the roof of a coal mine.

Nuts, small coal.

Ochre, earthy ores of iron are called ochres. They are generally red, yellow, or brown.

Old Men, the persons who worked a mine at any former period of which no record remains.

Old Men's Workings, workings made by the "old men," sometimes themselves called old men.

Open Cut, an open cutting.

Opens, large caverns.

Ore, any natural substance which is worked for the metal it contains.

Outcrop. *See* "Cropping out."

Overburden. *See* "Burden."

Overman, an overlooker.

Owner's Account Men, men paid at a fixed rate per day.

Oxide, any element which combined with the gas oxygen forms an oxide.

Packing. *See* "Tozing."

Pair or **Pare**, a party of miners who agree to work in partnership together. A pair of men usually consists of more than two and often of ten or twelve men.

Parcel, a heap of ore dressed and ready for sale.

Pass, an opening left for letting down ore and deads to any level.

Peach, the Cornish miners' term for chlorite.

Pick or **Pike**, slitter, mattock, pike-hake.

Pillar, an upright piece of a lode left to support its walls.

Pipe-vein, a vein of ore which is bounded above and below, as well as on both sides, by the "country."

Pit, a shaft.

Pitch, limit of the ground set to tributers or tut-work men.

Pitman, one who works in a shaft.

Pitman, one who has to look after the pumps and drainage of a mine. In Derbyshire, any underground worker.

Pitwork, the pumps and other appliances in the shaft.

Plug and Feather, instruments used in wedging off small masses of rock.

Plumb, soft.

Plumb, perpendicular or upright.

Plump, a Cornish term for a well.

Plutonic rocks, such rocks as are belived to have been formed deep down in the earth. Granite and porphyry or elvan are Plutonic rocks.

Pocket. *See* "Bunch."

Podar, anything that is brittle or worthless. The term is now applied to mundic, but yellow ore was formerly called podar when occurring in tin ores, as it reduced the value of the tin.

Point of Horse, the point at which a lode divides into two.

Poll, the "head," "pane," or striking part of a miner's hammer or of a poll-pick.

Poll-pick, a miner's pick, having one end sharp, and the other formed into a hammer.

Porous, containing minute pores or holes.

Porphyry, any rock in which distinct crystals of any kind are embedded in a non-crystallised mass. The elvans of Cornwall are porphyries.

Prian or **Pryan**, a soft clayey substance found in lodes.

Pricker, an instrument employed for making a communication through the tamping to the powder in a bore hole for the purpose of introducing a fuse or train.

Prill, a solid piece of pure metal from an assay. To "prill" a sample is to add some richer substance to it so as to obtain a false return.

Pulveriser, a machine for *grinding* ores instead of *stamping* them is now often so called.

Punch or **Punch Prop**, a timber support for the roof of a mine.

Purser, the person who is responsible for the accounts and pays the men in a mine. He is both treasurer and secretary.

Putter, one who conveys ore from the working to the horseway, or the bottom of shaft.

Pyritous, containing pyrites.

Quartz, a very abundant hard mineral substance.

Quartzose, containing or consisting chiefly of quartz.

Racks, a kind of frames for dressing tin ores.

Reduction of Ores, the extraction of the contained metal.

Riddle, a sieve.

Riddling, sifting.

Rider, a mass of rock dividing a vein. *See* "Horse."

Ringer, a crowbar.

Rise, to work upwards towards the surface.

Roasting. *See* "Burning."

Rod, the upright beam of a man-engine.

Roof, the part of a mine or level above the miner's head. In Cornwall called the "back"

Roughs or **Rows.** *See* "Croptin."

Run, when the parts of a mine or excavation fall together, they are said to "run."

Run of a Vein. *See* "Direction."

Sampler, the person who takes the samples of ores for assaying, or determining their value.

Scraper, an instrument for extracting the dust or rubbish from holes while boring.

Scrin, a small vein. Derbyshire term.

Seam, a bed of coal or iron ore is often so called.

Seat or **Sole,** the floor or bottom of a mine or level.

Set, to set or make an agreement with miners for the execution of any piece of work. *See* "Bargain."

Sett, the tract of land in which a mine is situated.

Setting-day, the day set apart once a month for making bargains with miners for the future working of a mine.

Shaft, a deep pit. All the deep pits in a mine sunk down *from the surface* are called shafts.

Shaft-pillar, a portion of ore left unwrought around a shaft for the sake of strength.

Shake, a fissure in the earth.

Shake, a quarryman's term for a crack in a block of stone.

Shift. *See* "Core."

Shode, to trace the position of a lode by observing the scattered loose stones from its upper part or "back."

Show, a pale blue tip to candle-flame indicating fire-damp.

Shutting or **Shooting,** blasting.

Sink, any excavation in a downward direction.

Sinking, digging downwards.

Skep. *See* "Skip."

Skimpings, the upper layer of impure tin ore, which is scraped off from that which has settled in a kieve. It is taken off and dressed over again by itself.

Skip, a kind of carriage in which ore is raised from the bottom of the mine, sometimes called a "skep."

Slag, a waste product formed in smelting ores.

Slate, a kind of rock which splits readily into thin layers.

Sled, a sledge without wheels. *See* "Corve."

Slide. *See* "Fault."

Slimes, fine mud containing particles of tin. *See* also "Croptin."

Slipes, flat pieces of iron for the corves to slide upon.

Slitter. *See* "Pick."

Sludger, an instrument for removing the mixture of dust and water, or "sludge," from bore holes.

Slyne. *See* "Joints."

Smalls, small coal or ore.

Smitham, small dust of lead ore.

Sollar, a small platform at the foot of a ladder in the shaft.

Sough, an adit.

Spale, a fine. For absenting himself from the mine without leave, or for breaking any of the rules of a mine, a man is liable to be fined or "spaled."

Spall, Spalling, breaking large stones of ore to a smaller size, so as more readily to pick out the barren, stony parts.

Spar, a Cornish miner's name for quartz. A Derbyshire name for fluor.
Spathose Iron Ore, Sparry Iron Ore, iron spar, or carbonate of iron.
Spel, a change or turn. Thus, if several men have to do a piece of heavy work upon which all cannot work at once, they change about, each taking a spel.
Spreaders, pieces of timber placed across a shaft which seems likely to fall in, to serve as a temporary support until it can be properly timbered.
Stamping, the breaking of ores into fine particles, in order that they may be dressed for sale.
Stamps, contrivances for stamping ores.
Stamps-head, the block of iron which forms the lower part of the stamps.
Standard, the price of metallic copper or tin.
Stem, a day's work.
Stemple, a strong beam placed in a slanting position, so as to support the walls of a lode.
Stemples, pieces of iron or wood fixed into the sides of a shaft to serve instead of ladders.
Stickings, narrow veins of ore, also capels.
Stone-axe, a tool used in dressing the surface of blocks of stone.
Stow, to pack away.
Stowce, a windlass.
Stowces, pieces of wood used to indicate possession of any part of a mine.
Stratified Rocks, rocks occurring in regular beds or strata.
Streamers, persons who work in streams in search for stream tin.
Stream Tin, that kind of tin ore which is obtained from stream-works. It is the most valuable kind of ore, and yields the purest tin.
Strik or **Streek**, to lower anything down a shaft by means of a windlass.
Strike, the direction of the outcrop of a bed of rock in a level country, or a line at right angles to its dip.
Strings, thin vein of ore in connection with a lode.
Stuff, the material raised from the mine, whether ore or deads.
Stull, timbers placed in the backs or upper parts of levels, and covered with poles or boards, to support the walls, or rubbish which it is not desired to bring to surface.
Sturt, a tribute bargain which turns out extraordinarily well for the miner is called a sturt.
Sump, the bottom of the engine-shaft, which is usually sunk below the deepest level, so as to form a pit in which the waters may collect before being pumped up.
Sumpmen, men who assist pitmen to keep the sumps clear.
Sump-shaft, the engine-shaft.
Swabstick, an instrument for removing dust and mud from bore-holes.
Swall, a cavern or opening into which water falls, and is lost sight of.

Syenite, a hard kind of granite containing hornblende.

Tackle, the ropes, chains, kibbles, and other arrangements for raising ore, etc., in connection with any shaft.

Tacklers, small chains to put round loaded corves to keep the coal or ore from falling off.

Tails, the roughest of the refuse tin, which is often stamped over again.

Tamping, the filling in of a bore-hole above the gunpowder with clay, etc., so as to secure a more effective blast.

Tamping, the material used in the above operation.

Tamping Arrow, a long and thin piece of metal used for making a communication through the tamping of a bore-hole with the powder at the bottom.

Tamping Bar, a bar used in driving in the tamping material in tamping a hole.

Thill, the floor of a mine.

Threads. *See* "Strings."

Throw. *See* "Fault."

Thrust, the falling in of a mine after supports are removed.

Thurst. *See* "Thrust."

Ticketings, the weekly meetings for the sale of ores.

Tie. *See* "Tye."

Tile Ore, a valuable ore of copper. A variety of red copper ore.

Timbering, the fixing of timber in a mine to support the sides of shafts, or the walls and roofs of levels is called timbering.

Timber-man, one whose duty it is to see to the timbering of a mine.

Tinner, tin miner, more commonly tin streamer.

Tinstone, the ordinary ore of tin, often called cassiterite.

Toadstone, a name used in the middle and north of England for the masses of basaltic rock which are often found forced up through the coal measures.

Tozing, the last operation in tin-dressing. The nearly clean ore is violently stirred up in a kieve with water, and then allowed to settle, while a continual knocking is kept up against the sides of the kieve.

Tramway, Tram, a railway suited for the passage of waggon-loads of ore or coal.

Trap, a general term often applied to all the various kinds of greenstone and basalt.

Tributer, one who works upon tribute.

Trouble, a "fault."

Trunk, a long, narrow pit into which the slimes are directed, so that the ore may subside.

Tubbing, the lining of timber or iron which is often applied in order to secure the sides of a shaft.

Tut-worker, one who works upon tut-work.

Tye, a long narrow channel (leading directly from the stamps) in which the stamped tin ore is often partially dressed.

Tying, washing.

Underlie, the amount of slope of a lode or vein, measured from the perpendicular. It is the same as the "dip" of

a bed, only that the dip is measured from the horizontal.

Unstratified Rocks, rocks not occurring in regular beds or strata.

Upcast, the ascending air current from a mine.

Uphill. *See* "Bord."

Vamping, the debris of a stope which forms a hard mass under the feet of the miner.

Vanning, the art of separating ores from veinstuff by washing on a shovel.

Vein, a lode.

Veinstone or **Veinstuff.** *See* "Gangue."

Ventilation, the art of removing foul or spent air, and of supplying pure and fresh air in its place.

Viewer, a superintendent.

Vugh, a cavity in a rock. A Cornish term.

Wall of a Lode, the side where it comes in contact with the surrounding country. In fig. 3, p. 27, the lode *underlies* to the left; the upper or left side *a a* is called the *hanging*, and the lower or right side *b b* the *foot* wall, a piece of waste land.

Wastrel, a tract of waste land, or any waste material.

Water-wheel, a wheel made to turn by a stream of water.

Wheal, the Cornish name for a mine, often and more properly spelt *huel*.

Whin, any very hard stone.

Whinstone, trap.

White Tin, metallic tin.

Whits, tin ore partially dressed.

Winding Engine, an engine used for drawing up ore.

Windlass, a machine used for raising weights.

Winds or **Winze**, a shaft which only communicates between two or several levels, but does not come to surface.

Work, the ore or other stuff which is raised from a mine. Thus, miners speak of rich work and poor work.

Yellow Ore, the miners' name for copper pyrites or chalcopyrite, the most common ore of copper.

Yokings. *See* "Stowces."

Yokes (yucks), used in lowering heavy pumps.

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